SPECIAL REPORT: CLEANING UP THE AIR TRAFFIC MESS

TECHNOLOGY REVIEW

MARCH 2001

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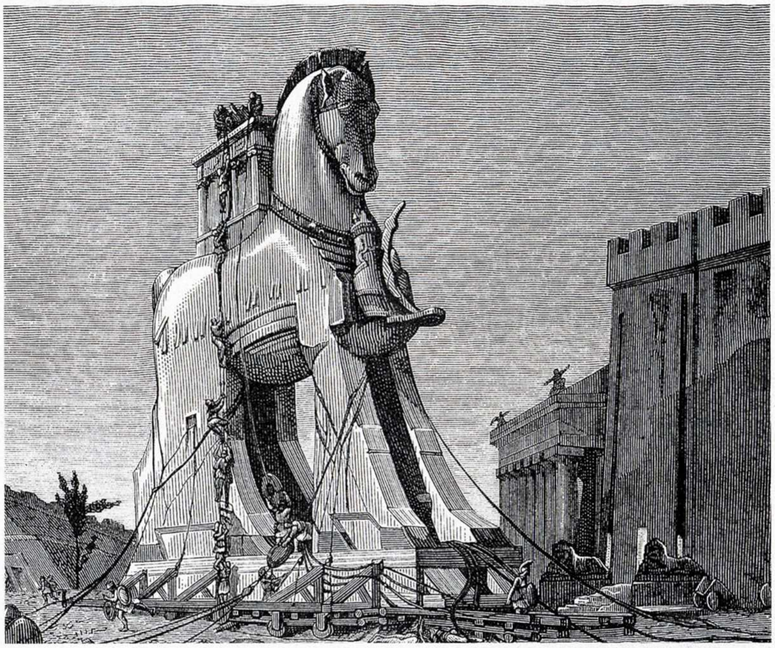

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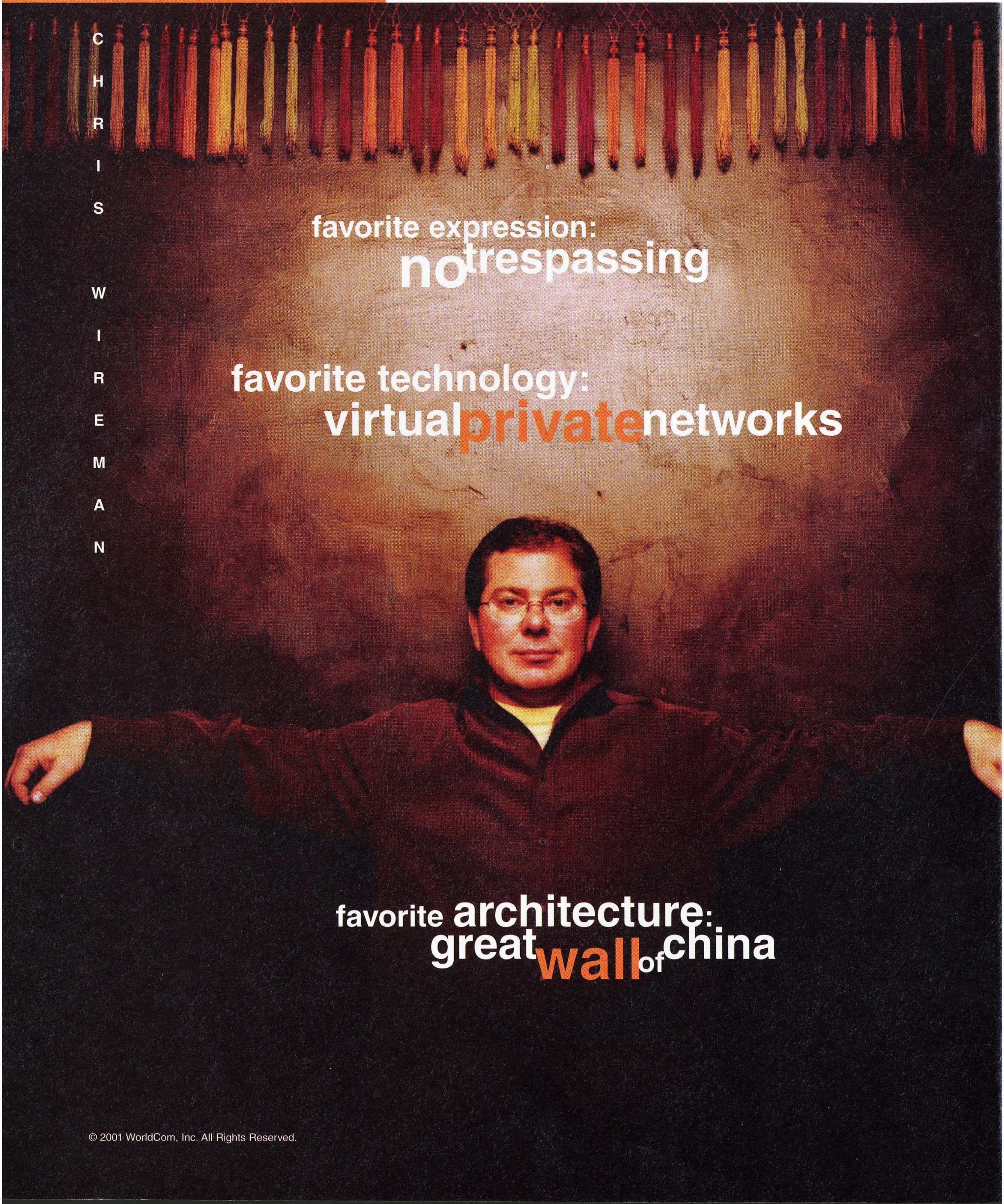

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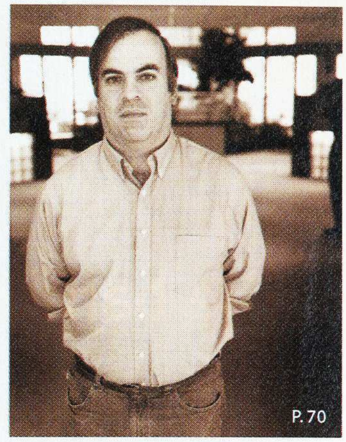

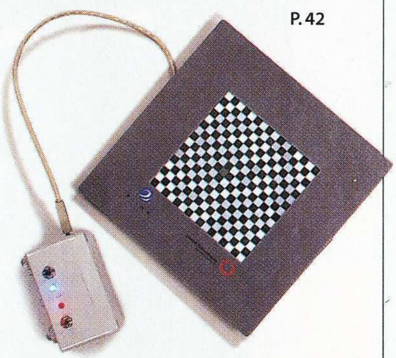

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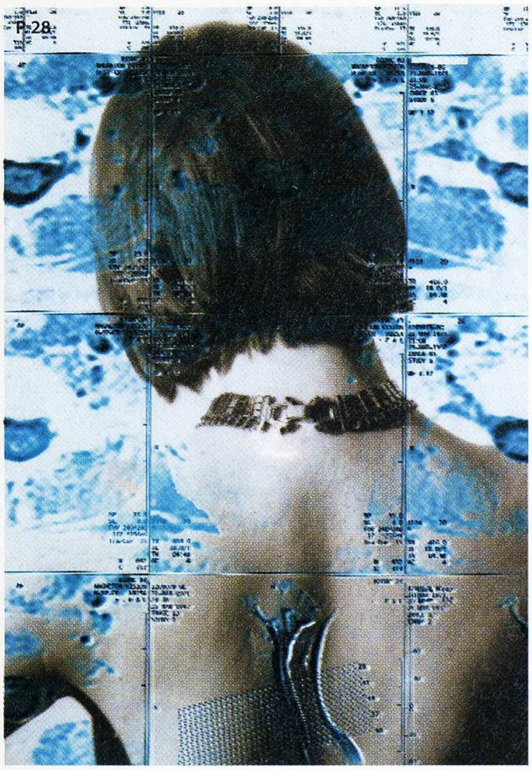

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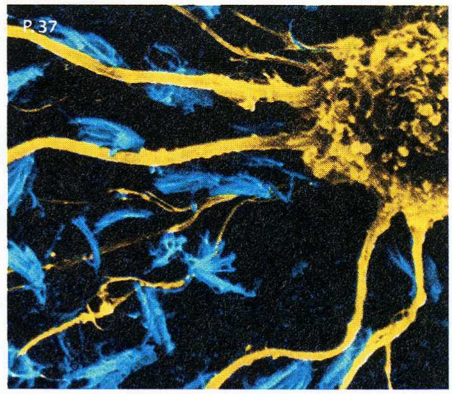

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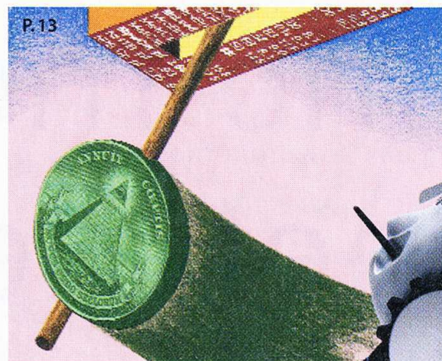

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DEPARTMENTS

COLUMNS

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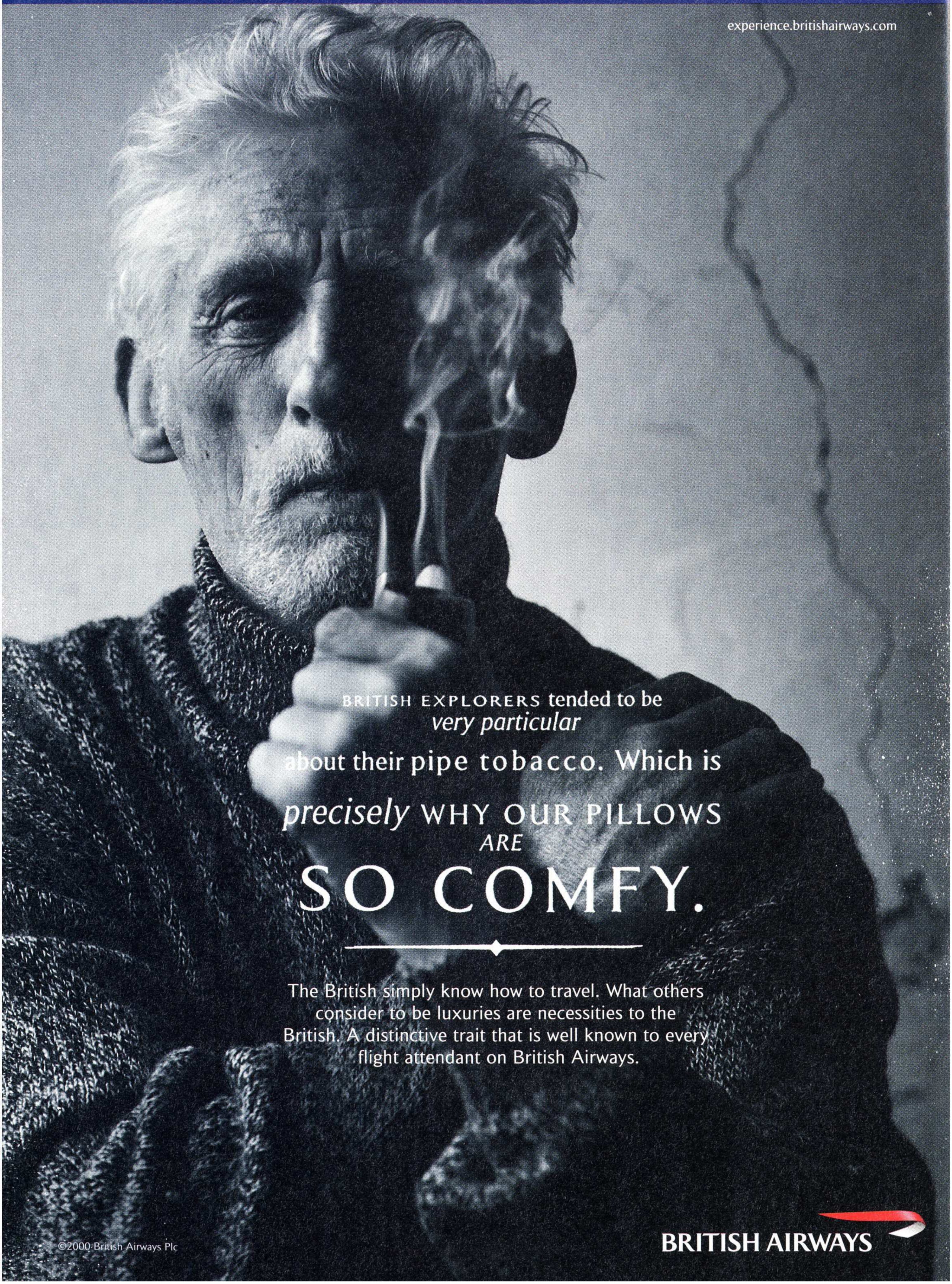
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New(d) Economy

"The Internet changes everything." "E-tailing." "Stock options—not salary!" "Dot-com billionaire." "Cyberspace." "Internet time." "B2C." "Free Agent Nation." "New Economy." Like the language of some Stone Age culture unearthed by an enterprising anthropologist after a five-day canoe trip upriver into the jungle, the vernacular of Internet hysteria is a whisper from another era, a language with a thousand words for Web and not a single word for profit.

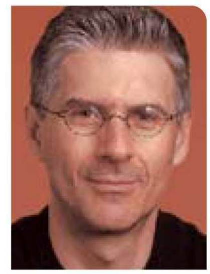
Of all the drivel that passed for visionary wisdom during the recent Internet psychosis, perhaps the sorriest was the idea of a "New Economy," based on the Web, that was going to colonize, dominate and finally dispatch an "Old Economy" rooted in antiquities such as cars, chemicals, copper wire—and clothing. That's the problem: this concept had no clothes. It was the Emperor's New Economy the whole time. But in the frenzy of the moment, few had the courage to say so.

For the record, this magazine has never been too impressed by the New(d) Economy. We are, of course, a technology publication, and we believe in the value and power of emerging technology. But our take on that power has little to do with heavy-breathing about the New Economy.

First of all, we don't think there is any such thing as a New Economy separate and distinct from some other, Old Economy. As Lou Gerstner, IBM's CEO, put it in the superb interview by Bob Buderi we published in our last issue *("What New Economy?",* TR *January/February 2001)*, the Internet *will* ultimately have a significant impact on how we live and do business. It will have that impact, however, not by carving out some new "space" we all migrate to but by transforming the way existing industries do business.

GENE GREIF

As Michael Dertouzos, another New Economy skeptic and frequent contributor to this magazine, likes to put it, when the automobile was invented, we didn't enter "autospace." We started driving, and ultimately the automobile did change many things. But not by creating "autospace." The same could be said of electric power or the telephone. There is no reason to think the Internet is going to be more transformative than these technologies.



Furthermore, in the New(d) Economy there isn't nearly enough attention given to human beings and their needs. It's a mirror world in which whatever is "cool" is produced. But information technology (like any other technology) is valuable only insofar as it satisfies human needs. There's no point in expending energy on things like ordering pet food online. Or storing your rolodex in your running shoe. Or having your refrigerator order your groceries.

As Dertouzos argued forcefully in his *TR* column "The People's Computer," machines exist to serve us, not the other way around. And the real Information Age will begin when the huge amount of repetitive data shuffling (i.e. office work) that humans now do begins to be done automatically by machines. Dertouzos's theme has been taken up by Michael Hawley in his column "Things that Matter."

Don't get me wrong: *Technology Review* believes technologies now on the horizon will make our lives very different. But that will happen only to the extent that these new tools respect human history and satisfy human needs—for more leisure, better health, freedom from drudgery, better communication with other human beings. Such changes won't by any means result only from information technology. One of the biggest New Economy blind spots is the failure to understand that information technology, while hot now, is only one of the major technologies that together will indeed "change everything." Two other fields we believe are destined to rise to the same level—and that consequently get a large share of this magazine's attention—are biotechnology and nanotechnology.

But the really profound changes will happen slowly, over a half century or more, and they won't happen in some arcane "space" of their own. They will happen right *here* where we all live and work and love. And when that transformation is over, only anthropologists will remember the dead language of the New(d) Economy.

—John Benditt

TECHNOLOGY REVIEW

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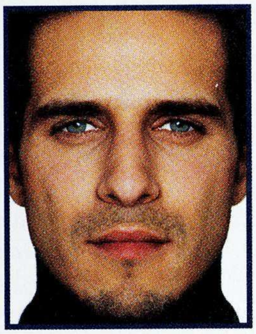
GOOD MORNING



Once again, today has arrived. And it brings with it the same meetings, the same problems, and, in many cases, the same solutions. Unfortunately, many of those same solutions aren't working. Because business has been transformed by the little letter e. And the technology that was once the domain of twentysomethings with a website and a warehouse in their garage is now an integral part of every business. Fortunately, however, the same principles that made for good management before still make good eBusiness sense. Of course, that's a lot more difficult now that your business isn't contained by four walls and needs to be accessible anywhere, anytime, for anyone. That's why it's more important than ever to have the very best software. Software that manages your business processes – integrating all parts of your company, including suppliers and partners, to make sure that they're working together seamlessly. Software that manages information – storing, accessing, and utilizing the vast wealth of knowledge that you continually gather about yourself and your customers. Software that manages your infrastructure – maintaining and securing your assets while letting you see the big picture to ensure that everything keeps running smoothly. There's no doubt about it. Things have changed. But that just means there will be new solutions to the old problems. And we think that's a change for the better.

HELLO TOMORROW

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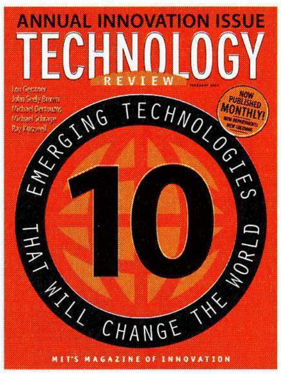
"Your article on passed technologies was one of the most interesting I've read in a while. You should do a weekly or monthly like this!"

The Great Debate

SWORD OR AXE, I BELIEVE THAT Michael Dertouzos and I are in agreement that technology has intertwined promise and peril as befits the profound duality of human nature ("Kurzweil vs. Dertouzos," *TR* January/February 2001). I do want to comment on Michael's discussion of my short précis on technology trends. Michael describes the creative process as proceeding in two stages: a nonlinear "crazy" stage in which wild new ideas are incubated, followed by a market-based filter which applies disciplined human judgment to determine which innovations will survive. As an inventor and entrepreneur myself, I fully agree with this description. But that's not what I'm talking about when I contrast the "intuitive linear" view of technological progress with the "historical exponential" view. I am making the point that the proven technologies, i.e., the ones that survive *both* the crazy stage and the filtering stage, progress in an exponential manner. The computers that are accelerating in their powers over time are the ones being successfully marketed, that is, the ones that have survived both stages of this process. The same can be said for many other aspects of technology innovation: communication bandwidths, biotechnology sequencing speeds, brain reverse engineering, miniaturization, and even the rate of paradigm shift are all progressing exponentially, not linearly.

I've enjoyed our exchange of views, and although Michael remains skeptical of the feasibility of the dangers that Bill Joy articulates, both Michael and I believe that we need to apply reasoned human wisdom to create the kind of world humans will want to live in.

RAY KURZWEIL
Wellesley Hills, MA



DERTOUZOS AND KURZWEIL DEBATED what we should do about new technology. However, the most important issues are their unstated assumptions. They appear to assume that somehow we will weigh their arguments and then decide to advance or limit new technologies according to the anticipated effects on humanity. Are the debaters proposing that there should be a worldwide or national referendum on every proposed research project? Or are they advocating that no technical advances be adopted without the approval of politicians, government bureaucrats or some anointed intellectual elite? Is it even possible to keep the genie in the bottle?

W. ALAN BURRIS
Pittsford, NY

WE NEED TO EXAMINE OURSELVES IN light of Dertouzos's argument. He speaks of a human limit for technology. Who draws that line? Those who develop technology form their own "techie" society and forget about all those human things out there. Then again, what do we expect from people who keep themselves in artificial environments (labs) all day long, and never study literature or history? If only all technologists were as broad minded as Dertouzos, or at least as mindful of their humanity!

SHALOM ROSENFELD
Flushing, NY

Tied to the Passed

"TEN PASSED TECHNOLOGIES" (*TR* January/February 2001) was one of the most interesting articles I've read in a while. I've dated myself somewhat since I've used some of the items mentioned (we still have an Amiga that my 15-year-old son toys with sometimes). You should do a weekly or monthly like this!

LYNN BUELL
Hutchinson, KS

THERE IS ACTUALLY ONE TYPE OF slide rule still manufactured, though not called that. The mechanical flight computer, a kind of specialized circular slide rule with additional plotting capabilities, seems to have survived in parallel with electronic flight computers.

JIM CERNY
Durham, NH

I WANTED TO MENTION THAT THE HINDENBURG exploded not because of the hydrogen inside the skin but because of the skin itself. The paint contained many chemical additives to keep it flexible on the soft skin. These chemicals are extremely flammable and ignited when hit by a spark during the storm. This is easily seen because hydrogen burns cleanly, but on the Hindenburg, the video clearly shows colored flames. Eyewitnesses called it a yellow-orange.

STEVE RADABAUGH
Athens, OH

WHILE THE FIRE THAT DESTROYED the Hindenburg got more attention, the destruction of the naval airship USS Shenandoah (ZR-1) in a 1925 Idaho thunderstorm pointed to a much more fundamental problem with zeppelins. Since they can't evade violent storms the way airplanes do, they have to be strong enough to survive them. However, any zeppelin with a frame strong enough to survive a serious storm is too heavy to fly.

WALT HAAS
Murray, UT

REGARDING THE SECTION TITLED "Automatic Watch," I'd like to point out that Seiko makes an affordable (around $200) watch called the Kinetic that does not need to be wound. The energy is stored electrically rather than mechanically.

BRIAN J. SAYATOVIC
Cincinnati, OH

We welcome letters to the editor.
Write: *Technology Review*, MIT Building W59-200, Cambridge, MA 02139. Fax: 617-258-8778.
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Letters may be edited for clarity and length.

DON'T FORGET WORDSTAR'S COMPANIONS. With CalcStar and DataStar, I could do mathematical, spreadsheet, and database computations that were unimaginable in 1982!

JIM TYLER
Ozark, AL

The *TR* 10

THE ARTICLE ON BIOMETRICS IS ESPECIALLY pertinent with regard to the last presidential election. In the future, biometrics could be used to prevent repeating the same fiasco. It could assure one person, one vote. Biometrics could screen invalid voters and prevent such scams as multiple voting. The necessary technologies either are available now or will be available by the end of this year (2001). A confirmation system could be viable by the next national election in 2004.

MAURICE CENTNER
Huntsville, AL

TWO FACTORS ARE SLOWING DOWN data mining, despite the many capable people and the opportunities afforded by new data collections.

First, advanced methods often lead to results that are obscure for anybody except niche users. For example, text mining has been plagued by output visuals that are based on elegant underlying mathematics but are poor matches to what ordinary users can understand.

Second, there has been too much reliance on so-called predictive methods, which aim to classify or grade new items based on a database of classes or grades assigned to old items. Open a textbook in any field and you'll see that most professional knowledge doesn't consist of methods for prediction but of facts, concepts, qualitative relationships, analogies and the like. Such knowledge underlies effective human action in any field; people can assimilate it into their existing knowledge web and apply it widely. Data mining will progress faster by becoming more attuned to knowledge and understanding as practiced by human beings.

RAUL VALDES-PEREZ
Senior Research Computer Scientist, Carnegie Mellon University, and President, Vivisimo
Pittsburgh, PA

Protect Our Kids?

JENKINS MISSES TWO DECISIVE DIFferences between high-school hallways and online teen chat rooms ("Digital Renaissance," *TR* January/February 2001).

Peer brutality, both physical and psychological, cannot be compared with the adult-on-kid variety. Kids in school can be unmerciful to each other, but, for the most part, they are restrained by the presence of adult supervision. And adults who prey on children in the real world have to contend with the presence of these same watchdogs.

On the Web, these guardian adults are removed, and access to the child is unlimited and unrestrained. Anyone can be a teen and join a teen chat room. The Web is a comparatively friendly place for the pedophile, the sado-masochist, or the one-night-stand predator. The same is true for peddlers of pornography or the latest suicidal cult.

The Web offers unique opportunities as well as threats for youngsters. While we shouldn't ignore the opportunities, we shouldn't gloss over the threats. Naive kids will eventually learn of the adult world.

BOB CHITESTER
McKean, PA

Jenkins responds:
Bob Chitester raises some important points. It is vital that we develop a realistic assessment of both the potentials and dangers of online life. There has been an exaggeration in recent years of the alleged dangers at the expense of serious attention to the meaningfulness of teen's online lives. Statistically, children are more at risk of sexual molestation at a church picnic or a Boy Scout outing than in cyberspace. The majority of unwanted sexual advances on kids come from family members or family friends, not strangers, suggesting the limits of adult protection of children's innocence in the home. The advent of the telephone also exposed children to the dangers of unwanted contact with the outside world. By and large, we responded to that risk by teaching children better ways to filter and respond to calls from strangers rather than denying them access to telephones. We do our children no service by pretending real world problems don't exist. Rather, we need to give them the skills to protect themselves and the chance to practice those skills in a relatively secure environment. We need to be careful to separate the adult urge to protect childhood innocence from the adult desire to control youth.

Cambodian Geeks

"THINGS THAT MATTER: KHMER KIDS Link to the Future" (*TR* January/February 2001) is exciting. These Cambodian schools will produce some of the finest computer-geek minds and push their country on to the cutting edge of technology in the world.

WES LARSON
Weslarson@onebox.com

OVER THE LAST SEVERAL YEARS, I developed a project for at-risk kids in Brazil (www.pcebrasil.org). I teach basic computer skills to local at-risk teenagers.

Despite the problems of poverty, violence and crime, I have seen some of these kids demonstrate how much they can learn with the help of computers.

It's great to hear about other projects with a similar vision to help at-risk kids in this world through computer training and technology.

PAUL CULL
Nova Friburgo, Rio de Janeiro
Brazil

MICHAEL HAWLEY WRITES THAT IN the Cambodian schools he's seen, "there is no segregation by race, age, intelligence or anything else, which is undoubtedly a healthier way to learn than the factory format used in most Western countries."

While peripheral to the point of Hawley's article, it is silly to contend that segregation by age or intelligence is an unhealthy basis on which to dole out education. How would someone whose mind struggles with junior college do at an intensely demanding institution? To assume individual growth can be best effected by homogeneous treatment is to naively ignore the depth of each human being's individuality. Nonetheless, I am particularly grateful that a spotlight has been thrown on www.cambodiaschools.com.

STEVE FREITAS
Newport Beach, CA

Doc in the Middle?

I ENJOYED MARC WORTMAN'S ARTICLE "Medicine Gets Personal" (*TR* January/February 2001). I was glad he made the point that "genes don't provide all the answers for treating disease." I was troubled, however, by the suggestion that, in the future, doctors will become simply middlemen, plugging a patient's genetic data into a supercomputer that will, in turn, tell the doctor which drugs to prescribe. There is already a popular perception—probably justified—that physicians are too eager to prescribe pills to treat every human ailment; too little emphasis is placed on assessing a patient's lifestyle and other "external" factors that, if changed even slightly, could alleviate symptoms without pharmaceutical intervention.

Most pharmaceutical companies will gain economic rewards from genetically tailored drugs. However, I am not convinced that people who are seeking medical treatment will benefit from a technology that accentuates physicians' propensities to prescribe drugs—rather than actually listening to their patients.

FRANK R. COTTINGHAM
Alexandria, VA

Not So Popular

RE: THE "POPULIST POWER TOOLS" (*TR* January/February 2001) commentary, let's make a pact, Seth—don't come to me with a problem, come to me with a solution! It's clear that Napster et al. have unwrapped the digitized music for all to poach—er, share—and the involvement of legal counsel speaks to the monetary consequences.

Knowledge can be replicated without being depleted. But it's the application of knowledge that creates value, not the cost to copy or steal it. We must reward those that take the time, and spend the money, to apply their knowledge in the creation of a unique piece of work.

Shame on the music industry for not reading the tea leaves—as they perfected the digitization of music they helped those P2P geeks build free libraries—but shame on Seth as well. To equate the value of an artist's work with the cost to copy it ignores the difference between knowledge and application and will attack the copyright system that preserves the reward given to artistry.

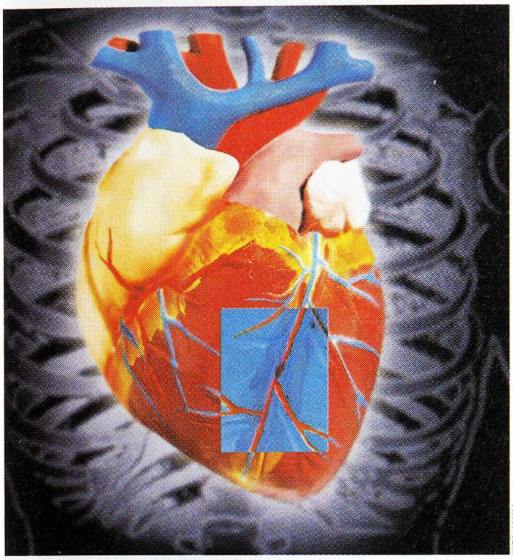
My proposed solution: let's solicit a reasonable system that helps music proliferate while offering the artist his rightful compensation. Our culture will sadly miss the contributions of creative genius if we allow the unsupervised P2P network to determine their worth.

MARK ROGERS
Encinitas, CA

Shulman responds:
You seriously misread me if you think that I don't want artists and innovators to be compensated. Or if you think I somehow conflate the cost of creating new songs or other intellectual property with the now-trivial cost of dissemination in the digital environment. Where we disagree, I think, is that I have come to perceive a powerful difference between robbing the candy store and sharing information in the digital environment. I believe that the fundamentally different, nonzero-sum economics at work in a knowledge-based economy force us to look at issues like Napster through fresh eyes. I don't pretend for a minute to have all the solutions. But sometimes, reframing the question can be an important first step.

PROTOTYPE

STRAIGHT FROM THE LAB: TECHNOLOGY'S FIRST DRAFT



VITO ALUIA

Special (Gene) Delivery

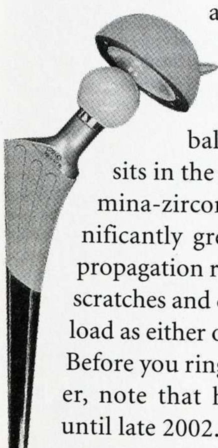
About a third of heart disease patients undergoing angioplasty to open up blocked arteries develop complications and even new blockages caused by stents—the tiny metal scaffolds inserted to hold the arteries open. Now researchers at the Children's Hospital of Philadelphia have developed a way to shield arteries from such complications using the stents themselves to deliver beneficial genes to the body. In contrast to other methods of gene therapy, which use viruses as carriers, this new approach depends on coating the stents with a biodegradable polymer containing therapeutic genes. In recent experiments, researchers inserted the coated stents into pigs' arteries and observed the polymer degrade, releasing genes into the arterial-wall cells. Once inside the cells, the genes began producing specific proteins. According to head researcher Robert Levy, the team is screening various candidate genes to find one that would not only protect blood vessels but also treat underlying heart disease. They hope to start human clinical trials within three years.

Smart Needle

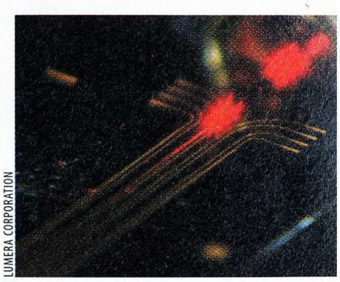
A medical probe under development at NASA promises to identify cancerous tumors without requiring surgical biopsies. San Jose, CA-based BioLuminate recently obtained a license from NASA to produce a disposable needle that makes real-time measurements of breast tissue to distinguish potentially cancerous masses. Sensors in the tip of the instrument register data such as tissue density, oxygen levels and density of blood vessels. The probe has the potential to significantly reduce the more than 16,000 unnecessary surgical breast biopsies performed weekly in the United States. The smart needle should be available for breast cancer detection in about three years. From there, the technology may be applied to identify prostate, colon, cervical and brain tumors.

Beyond Hip

Orthopedic implants like hips and knee joints last about 10 years, after which patients must undergo surgery to have them replaced. With longer life spans, an aging population and the increasing demand for prosthetics, the hunt is on for more durable faux bones. Now, a new ceramic developed by material scientists in France promises to extend an implant's life span to 30 years. A research team based at the National Institute for Applied Sciences in Lyon has developed a process that combines alumina and zirconia, two ceramics commonly used to replace the ball part of the femur that sits in the hip socket. The new alumina-zirconia composites boast significantly greater resistance to crack propagation resulting from defects and scratches and can handle twice as much load as either of the two ceramics alone. Before you ring up your doctor, however, note that human tests won't start until late 2002.



When Electron Met Photon

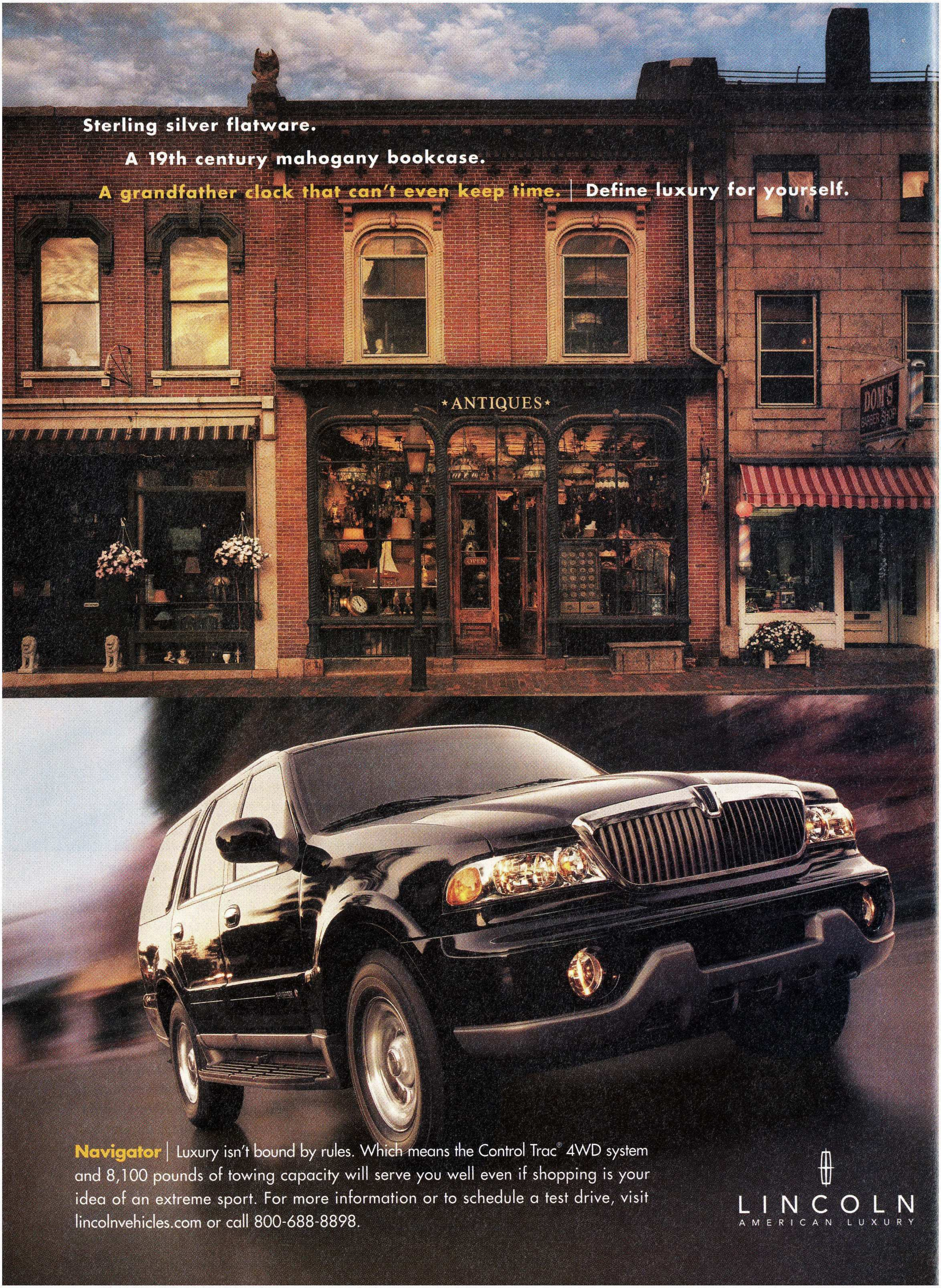


LUMERA CORPORATION

One of the largest bandwidth bottlenecks on the Internet occurs in the modulators and switches that translate the electrons used by computers into the photons that speed data through long-distance fiber-optic "backbone" lines. University of Washington, Seattle chemist Larry Dalton has found a way to accelerate this translation process with a new polymer. Modulators made from the polymer draw very little electrical power, are easy to integrate into electronic devices, and could improve communications speed tenfold. A new subsidiary of Microvision, called Lumera, owns an exclusive worldwide license on the polymer technology from the University of Washington; the Bothell, WA, outfit hopes to market polymer-based telecommunications devices in one to two years.

Rehab Robot

One of the most inspirational scenes in the movies is the one in which a paralyzed patient painstakingly relearns how to walk. In real life, however, it's often hard to find enough qualified therapists to provide timely rehabilitation. The solution may lie in robotics. With the help of neurophysiologists at the University of California, Los Angeles, engineers at NASA's Jet Propulsion Laboratory are developing a robotic stepper device that can speed rehabilitation of spinal cord and stroke patients. Taking the place of up to four therapists, the prototype treadmill device is equipped with robotic knee braces that attach to a patient's legs. Sensors continuously monitor 24 distinct data elements, such as force, speed, resistance, and number of steps. These measurements help therapists evaluate progress and adjust the stepper device accordingly. The experimental device could enter clinical trials at UCLA within three years.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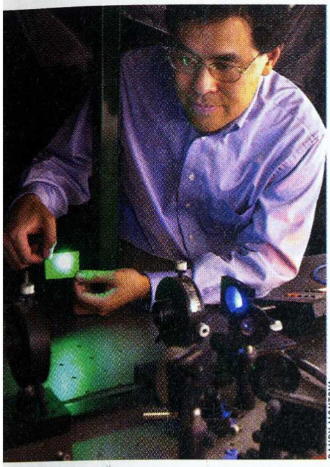
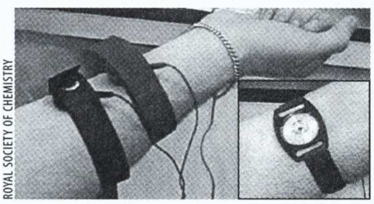

RANDY MONTOYA

New Light

Incandescent bulbs offer warm, but inefficient, illumination. Fluorescent lights save energy and last longer but cast a greenish glow. With the help of researchers at Brown University, engineers at Sandia National Laboratories in Albuquerque, NM, have come up with a brighter idea. They've developed a tiny solid-state laser that promises to deliver a longer-lasting white light while using minimal electricity. Related to the LEDs that blink in electronic appliances, the device emits ultraviolet light, which strikes a phosphor coating; the phosphor glows with an eye-pleasing white light. Lightbulbs made from the chips could last up to 10 times longer than fluorescent bulbs and up to 50 times longer than incandescent ones. The invention, only 20 micrometers square, requires the help of large conventional lasers; an electrically powered prototype should be ready within two years, with commercial models due in five to 10 years.

No Sweat


ROYAL SOCIETY OF CHEMISTRY

New sensor technologies have given rise to a faster and cheaper test for cystic fibrosis. Researchers at Dublin City University in Ireland have developed a diagnostic instrument that fits around a patient's wrist like a watch and produces results within 30 minutes. The device stimulates sweating by passing a chemical over the skin, then collects sweat samples and sends them to a separate unit where an array of sensors simultaneously measures sodium, chloride and potassium levels—which are significantly elevated in patients with the disease. The data is then fed to a laptop computer for analysis. While standard tests also use sweat samples, each ion must be analyzed separately using different techniques, a process that can take up to a day. According to Dublin City chemist Dermot Diamond, the ultimate goal is to integrate the sampling device and the sensors into a single unit equipped with a radio transmitter to send data to a remote computer for analysis.

Zippy Chips

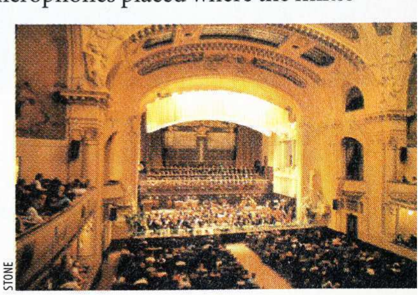
In the semiconductor world, one of the biggest performance bottlenecks is the link between separate chips on a circuit board. The more circuitry you can stuff onto a single chip, the faster it will perform and the less power it will draw—a key consideration in today's tiny consumer electronics. Large, complex chips, however, have a high failure rate during production, and the main alternative—bonding smaller chips together—requires high temperatures, which lead to defects after cooling. Now Ziptronix, a commercial spinoff of the Research Triangle Institute, has hit upon a better way. The Research Triangle Park, NC-based company has succeeded in pressing together two wafers (the thin sheets of semiconductor material on which computer chips are grown and etched) at room temperature, bonding the chips on one to the surface of the other. Cutting away the donor wafer leaves its chips embedded on the host. Connect the resulting circuits and you have twice the transistors on one chip. The process can be repeated as many times, and with as many different semiconductors (gallium arsenide, indium phosphide), as required. Products built using the technology could be on the market by early 2002.

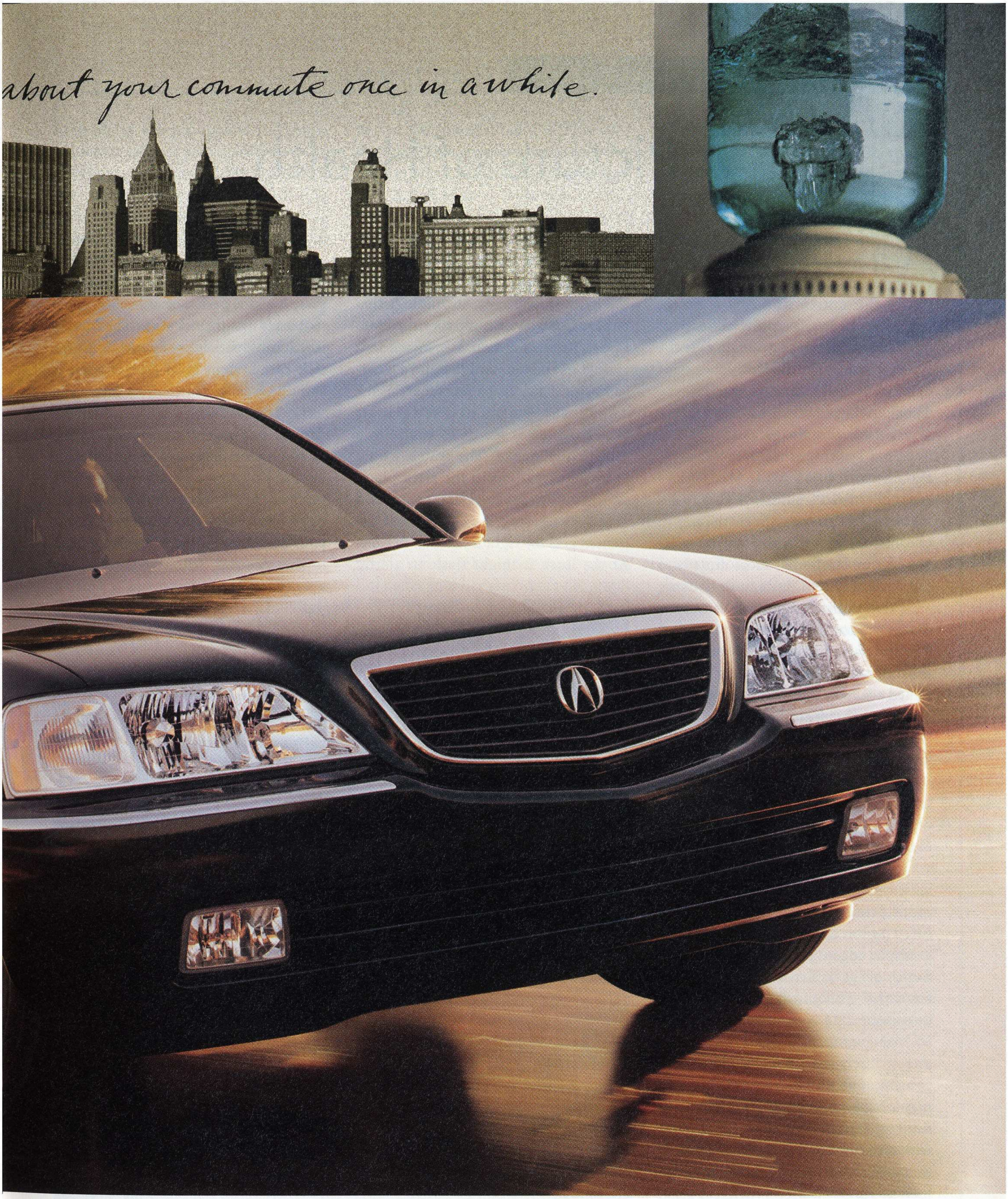
Finer Networking

The more finely you can slice the optical spectrum into distinct signal-carrying channels, the more data you can send through an optical fiber. That's the idea behind wavelength division multiplexing, which has brought tremendous data-carrying capacity to fiber-optic communications systems. Now Columbia, MD-based Essex has developed a variation on this technology designed to improve the lower-capacity optical networks extending from intercity fiber backbones into metropolitan areas. Essex's "Hyperfine" technology subdivides each optical channel into 50 to 100 subchannels, separated by less than a hundredth of a nanometer. So far, Essex has demonstrated this spacing over a wavelength band of about 0.1 nanometers, but the company plans to demonstrate an industry-standard 0.4-nanometer version early this year. In addition to providing better performance over existing fiber, the company claims the technology can better "tune" or control each of these channels, providing more flexible deployment of optical lines to specific corporate customers.

Virtual Microphone

Until recently, concert recordings were made in stereo, with only left and right audio channels. The advent of digital-videodisc audio technology makes richer, six-channel reproductions possible, but only for musical events originally recorded on multiple channels. Reinventing the past, Chris Kyriakakis, co-director of the Immersive Audio Lab at the University of Southern California, has found a way to revamp existing recordings by "mapping" the concert halls where they were made. Kyriakakis places arrays of microphones around the venues, then electronically compares their signals to those of reference microphones placed where the mikes were located during the original recordings. This comparison yields enough information to translate the original recording into a six-channel recording. For Internet delivery, only one or two channels need be sent; the rest are generated at playback.


STONE



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A Picture of Health

As I stepped on the bathroom scale, my life flashed before my eyes. I looked into the mirror and saw a graph, magically overlaid on my reflection. The red line plotting my weight over the last year looked like the Dow Jones average, with little bumps during the Thanksgiving and Christmas eatathons. It was a sobering image.

That system, called NetWeight, is the invention of MIT Media Lab researcher Brad Geilfuss. With it, Brad argued a fundamental thesis: the way to revolutionize medical practice is by connecting our bodies more directly to the medical system. Since most of us are a captive audience for a few minutes a day in the bathroom, he started there. The scale was a networked sensor. The mirror gave you an "inner view": it contained a Silicon Graphics computer and a video projector that overlaid live graphics on your reflection. The weight graph could appear on your beer belly.

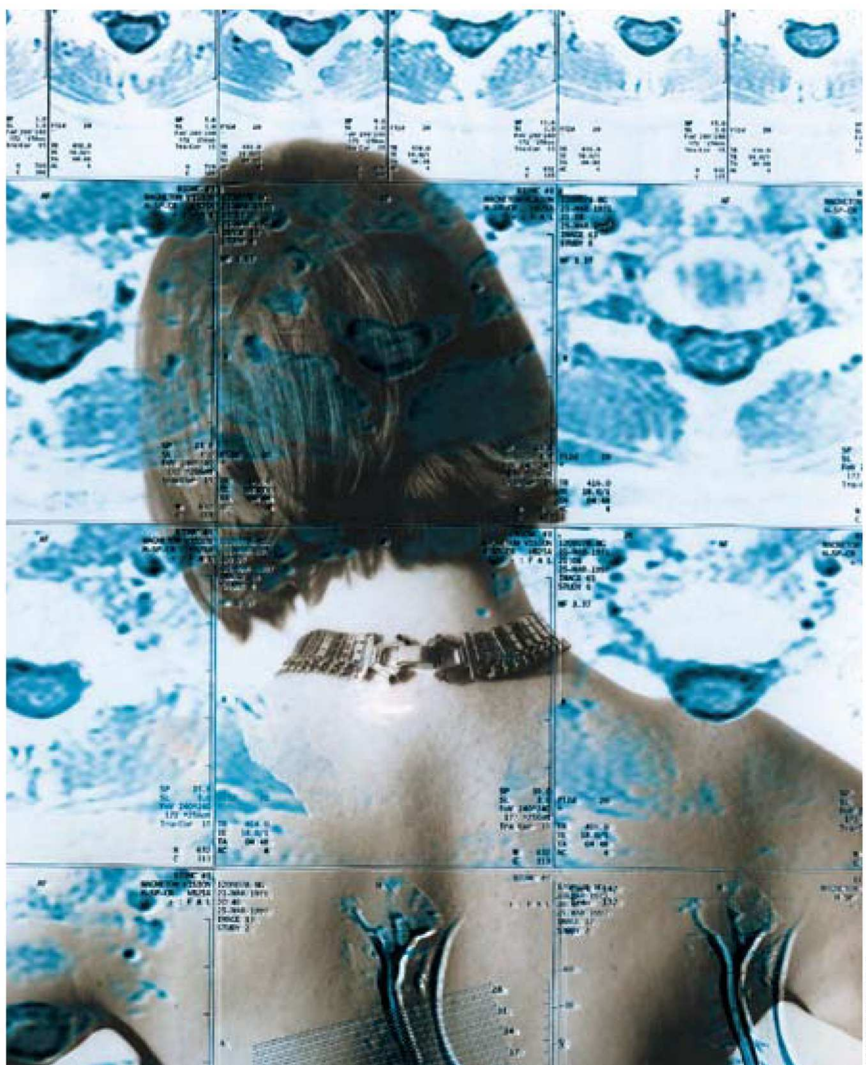
Before you run screaming from the littlest room in your house with visions of Big Brother watching your every excretion, let's think this through.

The problem of staying in touch with our health goes far beyond just monitoring flab. For example: there isn't a person on the planet who has seen a simple, cogent picture that traces the health of his or her heart over the last few years. This can have grave consequences.

Americans suffer 1.5 million heart attacks each year, but only about 10 percent of victims receive timely treatment. When you have an attack, you need an injection of an anticoagulant within an hour or two. Wait longer than that and the drug may do more harm than good. Of course, by then it's often moot. The muscle has begun to die. In any event, it's far more expensive to care for someone who has been felled by a heart attack than to nip one in its early stages.

Why do most heart attack victims fail to get treatment in time? The biggest source of delay, it turns out, is that people are disconnected from their bodies. We ignore symptoms. Technology that either exists now or could soon be developed offers a solution. For instance, it should not be too hard to build a wristwatch for high-risk patients that has the cardiological smarts to detect a heart attack, which is about as subtle as a 7.0 Richter quake. The watch would send the right blip to the right place, summoning medical attention and greatly increasing the chance that the patient gets the right treatment in time. At the least, it might flash an alarm: *Four hours to live! Call this number.*

Of course, heart problems are about much more than a few critical moments: there is a long period of unhealthy living that leads into the risk zone. The trouble is that most people are flying blind. Our sick-care system (and that is what it should be called, since most folks only use it after blowing a gasket, after the damage has been done) is built on the quaint notion that you'll visit the doctor once in a blue moon and provide a pinprick of data that somehow enables the physician to keep you healthy. But once your body is online, just getting dressed in the morning will activate a "body network" of jewelry, apparel and appliances that collects more vital data every



STEPHEN SHEFFIELD

day than your doctor sees in a year. You may be able to see the early warning signs of heart disease in graphic detail when there's plenty of time to do something about it—and the sporadic medical checkup will go the way of the dodo.

The last time vital-sign monitoring was substantially improved, the result transformed hospitals. Around 1863, Karl Wunderlich proposed a standard medical chart that would hang on the end of a hospital bed. His chart showed temperature, pulse, and respiration data, so that a physician could monitor a patient's progress at a glance. That basic tool probably had more impact on the quality of hospital care than anything other than drugs and antiseptics. The application of new technologies to the convenient tracking of an individual's health status promises even greater change today.

The personal vital-sign monitors in the coming wave are wearable, networkable, even fashionable and fun. The implications of these inventions go far beyond hospital critical-care rooms. Some signs of the times:

- MIT researchers run the Boston Marathon sporting fanny-pack body monitors that transmit their stats (pulse, stride, body temperature) to the Internet. Similar technology was tested by climbers on Mount Everest.
- Olympic sprinter Michael Johnson wears ultrasmall accelerometers that analyze the kinematics and physiology of his 400-meter dashes. Champion bicycle racer Lance Armstrong uses new bike-mounted sensing systems to radically improve his performance.
- Companies like FitSense and Nike have introduced watches with radio links to their shoes. The watch is a "dashboard" that precisely tracks how far you run; FitSense's watch even transmits the results to the Web.

Some technologies are exotic. The Media Lab marathoners swallowed a horse pill that measured internal temperature and radioed the results to a belt-buckle receiver. Since the circuit is cast in a plastic shell that keeps it from reacting chemically with the body, approval from the U.S. Food and Drug Administration was a breeze. John Glenn used the same pill sensor system in his latest space flight. That pill lent itself to a classic demo: place a graduate student near a computer, feed her a pill, and observe the temperature graph on the screen. Then pour some piping hot coffee into her and watch the graph go up. Then some ice cold beer. Then some piping hot coffee…

Annual doctor checkups? How quaint. Networks of wearable or ingestible sensors, along with smart household appliances, can much more effectively track the condition of your body.

This cycling is much like what one observes in marathoners. Body temperature goes up for the first few kilometers. But at about kilometer 30, temperature starts to fall off a cliff: having burned up all the fuel in the furnace, the body begins to get cold. (On closer inspection, the temperature moves up and down, with periodic dips every few kilometers. Each dip turns out to be a cold swig of Gatorade.)

MIT student Maria Redin gave the technology a romantic twist. Working with Ronald Winston, president of the Harry Winston jewelry company in Manhattan, she created the Heart Throb Brooch, a lavish diamond-and-ruby pin. The rubies glow with every heartbeat. A transmitter carried in a clutch purse or built into an Armani eyeglass case sends the signal to the Net.

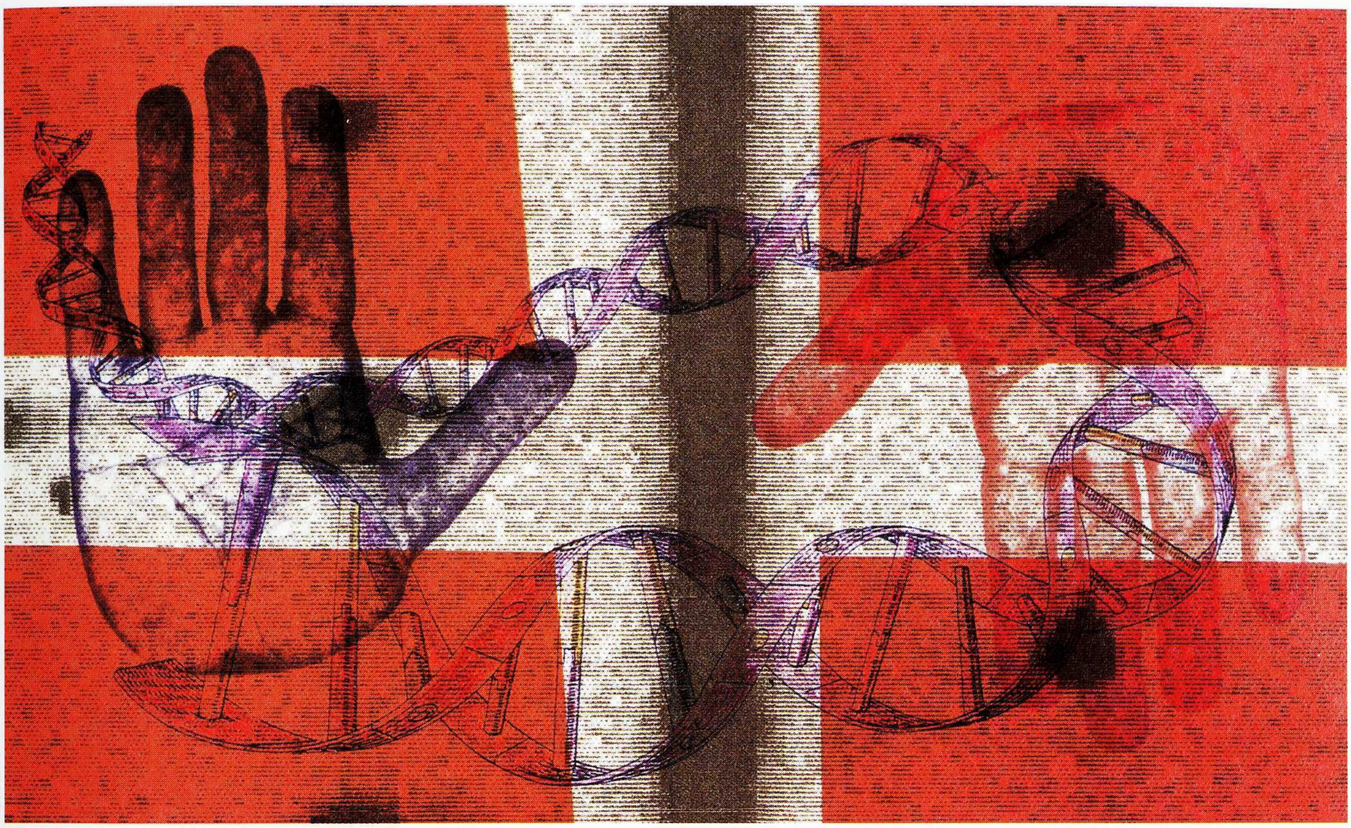
Flashy jewelry suggests a way to turn health monitoring into a killer app (no pun intended). Jewelry touches (even pierces) the skin in places like earlobes, necks, wrists and fingers. Often it is worn near the heart. So it is well situated to monitor vital signs. Jewelry also can be expensive, which may be seen as a feature, not a bug: with all those Winston diamonds, you'll hardly notice the cost of the technology. And jewelry is an enticement to accessorize. It invites a networked ensemble, a set of sensible jewels that form a little internet around the body. Finally, jewelry exists to communicate. It signals your status and tastes to partners or potential mates. (Redin conceived of the Heart Throb in a "His & Hers" configuration: one spouse might wear a sensor, the other the jeweled "display," and when the two drew close at a party, one would glow like a Christmas tree.)

And it won't stop there. High-definition television may finally find its place in retinal implants (wouldn't you like better night vision or eyes with 200:1 zoom?). Clearly, the coming decades will see startling advances in human body networking: we will live through revolutions in wearable, edible, implantable, sense-able, fashionable, tasty ensembles of devices. Within 10 years we will probably take the notion of placing our bodies online for granted.

Patients going in for elective open-heart surgery are asked two questions: (1) do you have a spouse/lover/confidante? (2) do you regularly hang out with a group (church/synagogue/bowling league)? Six months later, those who answer yes to both questions have a seven-times better chance of being alive. This suggests that technologies that are connective, that help us better see ourselves, and help us share that picture with those close to us, can really pay off.

To our grandchildren, the notion of Doctor Jellyfinger collecting a pinprick of data will seem as archaic as treating cholera with leeches, and an absurd basis for a health-care system. In their world, vital signs will be sampled casually and continually by sensor-laden garments and jewelry. They will wonder what a regular checkup was, or how their grandparents lived in a world in which they knew more about the state of their cars than about their own bodies. This isn't just an ounce of prevention, but gigabytes of it, for a health-care system that provides most Americans with 1930s-era treatment.

It's time for a new bathroom scale. Got the picture? ◊



IRAIDA ICAZA

Biochips Go Big Time

Microelectronic and communications firms turn to life sciences

BIOTECH | In the last few years, the biotech industry has set out to establish its own version of Moore's Law, shrinking the tools of the trade onto postage-stamp-sized "biochips." The hope is that the smaller/faster/cheaper approach that worked so well for computer-chip manufacturers will be a boon to biotech as well. The success of early biochip startups like Santa Clara, CA-based Affymetrix has helped to establish the field, and now giants from microelectronics and communications are moving in as well.

Motorola, Hitachi, Corning and others are entering the biochip business in anticipation of a market expected to grow to $10 billion within the next five to 10 years. "Biochips are the next big thing, so it behooves us to get involved in this industry," says Mark McDonald, president of Hitachi Instruments. The most common strategy for these high-tech titans has been to forge alliances with smaller biotech companies. Motorola has partnered with more than half-a-dozen companies, and last year it acquired Pasadena, CA-based Clinical Micro Sensors for its DNA biochip technology.

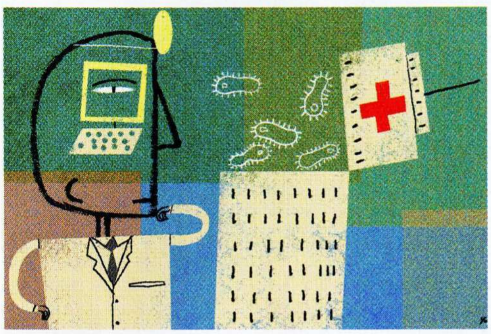
For the semiconductor chip makers, biochips are a natural fit. Motorola is applying the same techniques it uses for manufacturing integrated circuit boards to the production of one type of biochip, whose surface contains tiny electrodes attached to fragments of DNA. Using technology found in sensors for airbags, the company is also developing biochip devices for detecting infectious diseases.

The term "biochips" actually refers to both DNA microarrays or "gene chips"—DNA-covered pieces of glass or plastic capable of analyzing thousands of genes at a time—and microfluidic chips, which contain networks of microscopic channels and reservoirs for processing and analyzing biological samples. The goal is to use these tools to better understand the role played by genes in health and disease, to speed the development of drugs, to improve diagnostic tools, and even to build handheld devices that test for microbes in food.

If the demand for such devices booms as expected, the smaller firms will need the manufacturing power of big industrial partners to keep products on the shelf. And even though early biochip firms such as Affymetrix will likely continue to churn out chips as well, they'll no longer be the only game in town. **—Alexandra Stikeman**

Debugging Hospitals

DATA MINING | Hospital-acquired infections kill about 90,000 people every year in the United States and account for half of all major in-hospital medical complications. "If you find these outbreaks and act on them, you can cut down on the number of infections," says Stephen E. Brossette, president of Birmingham, AL-based MedMined and pathology resident and researcher at the University of Alabama, Birmingham. "Finding them is the problem." Hospital infection-control staff typically hunt for outbreaks by thumbing through hundreds of pages of results from every test for microbes performed by their hospital labs. In such an ocean of data, only the largest and most conspicuous outbreaks get caught.



JAMES YANG

To catch what humans miss, Brossette is using computers that comb through these vast data sets. When he was a graduate student at UAB, he and Associate Professor Stephen A. Moser developed a tool called the Data Mining Surveillance System (DMSS) that sniffs out patterns in medical data that are too subtle or complex for humans to detect. When MedMined recently used DMSS to crunch 11 months' worth of lab data from a 600-bed tertiary-care medical center in Alabama, the system identified 41 suspected outbreaks; subsequent inspection of patients' charts revealed that 97 percent actually had hospital-acquired infections. During that same period, the medical center's infection control staff had flagged only nine suspected outbreaks, just three of which turned out to be real.

MedMined currently uses DMSS to analyze lab data from five U.S. hospitals. The technology has already gained attention from, among others, the Centers for Disease Control and Prevention (CDC). "[The CDC] has always been keenly interested in accurate ways of detecting health care-associated infections," says Lance R. Peterson, director of the CDC's Prevention Epicenter at Northwestern Memorial Hospital and professor of pathology and medicine at Northwestern University. "In the future [the MedMined approach] has the potential to develop into a national surveillance method for detecting food-borne infectious disease outbreaks—and perhaps even more," Peterson says.

—Deborah Kreuze

Fuel Cells: A Lot of Hot Air?

AUTOMOTIVE | Under growing pressure to improve energy efficiency, automakers around the world have already spent approximately $2 billion to develop electric cars powered by fuel cells. The technology involved, which uses hydrogen to generate electricity, has been heralded as the key to tomorrow's cleaner-running car. But is it really environmentally friendlier?

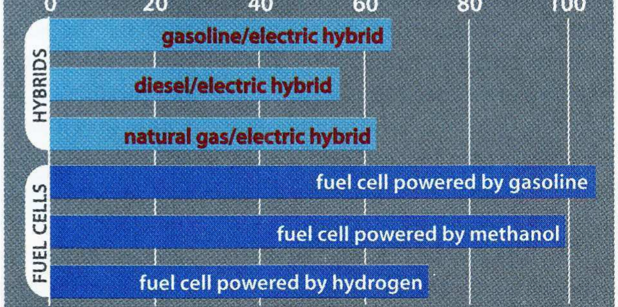
In the short term, the answer is no, according to a recent MIT study. Over the next two decades, fuel cells will deliver an environmental performance only slightly better than advanced versions of the familiar internal-combustion gasoline engine, the study says. During that time, another technology—internal combustion/electric hybrid cars like the Honda Insight and Toyota Prius, which premiered last year—promises the lowest energy consumption and emissions.

If every corner gas station sold hydrogen, fuel cells would be more efficient and competitive. But as a practical matter, hydrogen must first be extracted from today's widely available fuels, like gasoline and methanol. "Fuel cells offer no important advantages over other technologies," says Malcolm Weiss, who headed the MIT study, with funding from four oil companies, Ford, and a foundation. "You can more quickly and easily produce and introduce improvements in traditional technologies than new technologies."

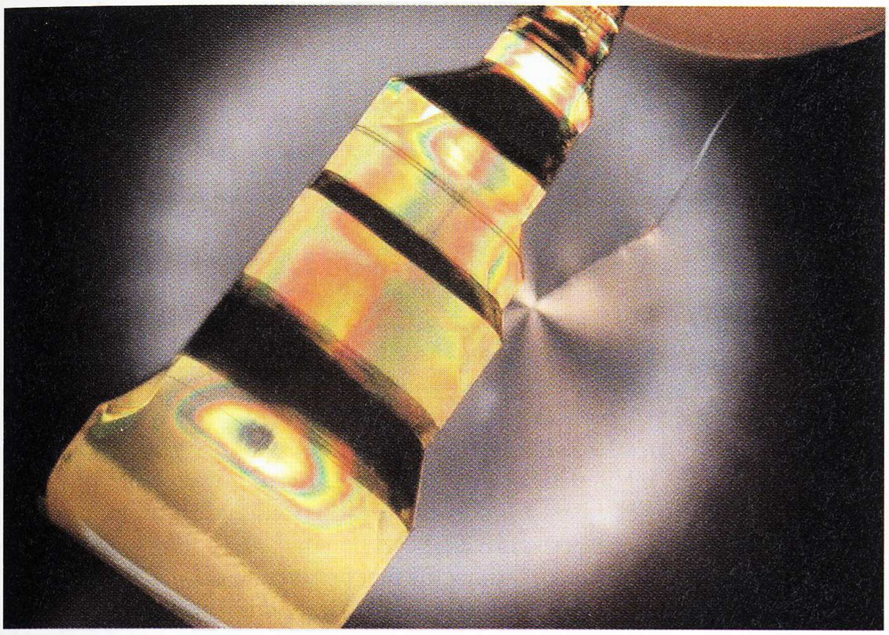
The study used computer simulations of various combinations of fuels and engines and included the "life cycle" energy costs of building the engines and producing the fuel. The study concluded that in 2020, internal combustion/electric hybrids will consume about 55 to 65 percent of the energy of an advanced gasoline car, while fuel cell/electric hybrids will consume more: 72 to 104 percent.

Fuel cells have a better chance beyond 2020, when hydrogen may be more available, says Brendan Prebo of Ford, which is in partnership to sell a fuel-cell car in 2004. He said the findings "aren't that big a surprise." **—Jules Crittenden**

By 2020, the life-cycle energy costs of internal-combustion/electric hybrids will be 35 to 45 percent lower than those of internal-combustion engines (100 percent). Fuel cells won't fare as well.



SOURCE: MIT ENERGY LABORATORY



TRELLIS PHOTONICS

Trellis Photonics' speedy optical switch is based on holograms etched into crystals. The crystal above will be cut into 1,000 smaller crystals which are then polished, etched and arranged in a "trellis" design.

A Better Optical Switch

Holography takes optical switching to nanosecond speeds

FIBER OPTICS | The dream of a speedy all-optical Internet has so far been thwarted by a vexing bottleneck: optical switches must convert data to an electrical signal to switch data from one optical fiber to the next, then convert the data back to optical to speed it on its way. This conversion requires costly and bulky equipment, and when you scale up to the high-bandwidth data streams demanded by the latest optical networks, these switches are no longer cost-effective. A better solution is an all-optical device that can affordably switch gigabytes of data without skipping a beat.

Researchers have tried optical switching devices such as arrays of tiny mirrors, liquid crystals and ink-jet bubbles, but an Israeli startup called Trellis Photonics may have a better idea: holograms. The company claims its new "electroholographic" device is as scalable as mirrors while offering faster switching and better reliability. Developed by Aharon J. Agranat at the California Institute of Technology and the Hebrew University of Jerusalem, Trellis's technology creates ribbonlike holograms within crystals that are arranged in rows and columns like a trellis. When electrically charged, the holograms can selectively deflect specific colors onto new paths, while the rest of the light wavelengths pass through unaffected.

The device can switch data in as little as 10 nanoseconds (billionths of a second), which is comparable to the speed of optical-electrical switches, and future versions will switch even faster. Yet in today's market, an optical switch is judged by the number of wavelengths it can process, not the speed of its switching. "At this point, nanosecond switching doesn't really matter," says Jay Patel, an analyst at the Yankee Group. But Sterling Perrin, an analyst at IDC, suggests the switch's quickness may eventually bear fruit when intelligent optical routers are developed that can analyze and optimize the path of individual data packets. Says Perrin, "That's when you'll need a switch with nanosecond speeds."

Trellis Photonics recently received a secondary $25 million round of venture funding. Carriers will beta-test the Trellis device this spring, with general availability planned for the fall. If it lives up to its billing, the dream of an all-optical network could be closer than expected.

—Eric S. Brown

Robot Ramp-Up

VENTURE CAPITAL | Over the past two decades, a good way to scare away venture capital was to tell investors you wanted to build robots. Earlier robotics companies typically flopped when it became clear the computational power didn't exist to drive the fine sensory and motor capabilities required of even the simplest devices. But with companies now producing robots that do things like paint ship hulls or remotely stroll the office, bankers at Chicago-based Olympic Cascade Financial believe the technology has finally caught up with the promise.

Cascade has established what it says is the first-ever venture-capital fund created exclusively for robotics. So far the fund, Robotic Ventures, has raised an initial $5 million from investors and identified a dozen potential recipients, all companies ready to bring robotic devices to market.

"You're going to see a lot of robots," promises Brian Friedman, co-director of the fund with Rodney Brooks, director of MIT's Artificial Intelligence Lab. "The revolution that people conceptualized in the 1970s and '80s is now a reality in the year 2001."

Friedman said the company Brooks co-founded, iRobot, will likely receive Robotic Ventures funds to refine and market products like its flagship iRobot-LE (below)—an Internet-ready communications robot that can, among other things, roll around the house and check on the cat while you are on vacation. Other potential recipients include robotics companies serving the shipping-, oil- and gas-services industries.

IROBOT

If the fund proves profitable, Robotic Ventures plans to set up a second, larger fund that will focus on early-stage robotics companies.

—David Talbot

Industry Hugs Biotech Trees

Proponents of genetically modified forests could seek the regulatory green light in four years

AGRICULTURE | First there were herbicide-tolerant soybeans and worm-resistant corn. Despite the controversy swirling around such genetically engineered crops, they are now planted on millions of hectares of U.S. farmland. And there are growing indications biotech trees will be next.

Three of the world's largest paper and lumber producers have formed a joint venture, called ArborGen, that hopes to be the first group to commercialize genetically modified trees. ArborGen expects to seek approval from the U.S. Department of Agriculture and other regulatory bodies for mass planting by 2005. Based in Summerville, SC, the company has access to the vast research base of its corporate parents: International Paper, Westvaco, and Fletcher Challenge Forests, plus a New Zealand-based genomics company, Genesis Research and Development.

What tree is a likely first candidate? ArborGen isn't saying. But the venture has access to several technologies for tree modification. Among them are ways to suppress genes that produce lignin, a plant component that must be chemically removed to make paper. Other technologies include ways to make trees herbicide tolerant and to minimize crossbreeding risks by controlling their ability to reproduce.

Sampling of U.S. Research on Genetically Modified Trees

ORGANIZATION	SPECIES	DESIRED TRAIT
Michigan Tech, MI	Poplar	Reduced lignin content
Westvaco, NY	Pine, sweet gum	Altered plant development
Exelixis Plant Sciences, OR	Apple	Altered fruit ripening
International Paper, NY	Sweet gum	Herbicide resistance
University of Wisconsin, WI	Poplar, spruce	Resistance to moths
Cornell University, NY	Apple	Disease resistance
Oregon State University, OR	Poplar	Insect resistance, herbicide tolerance, reproductive control

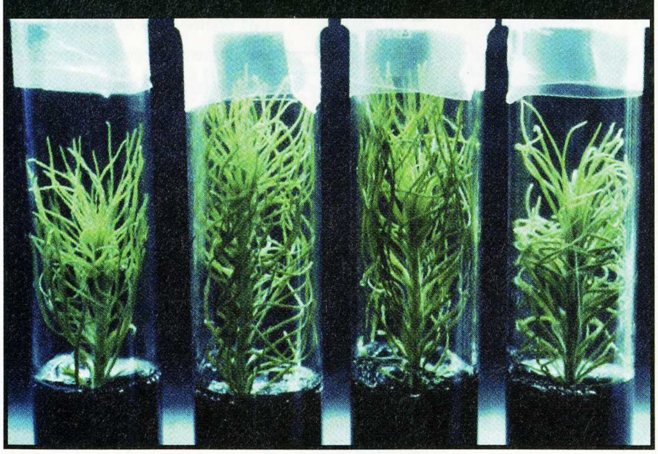


IMAGE: WESTVACO; TABLE: ARBORGEN, USDA

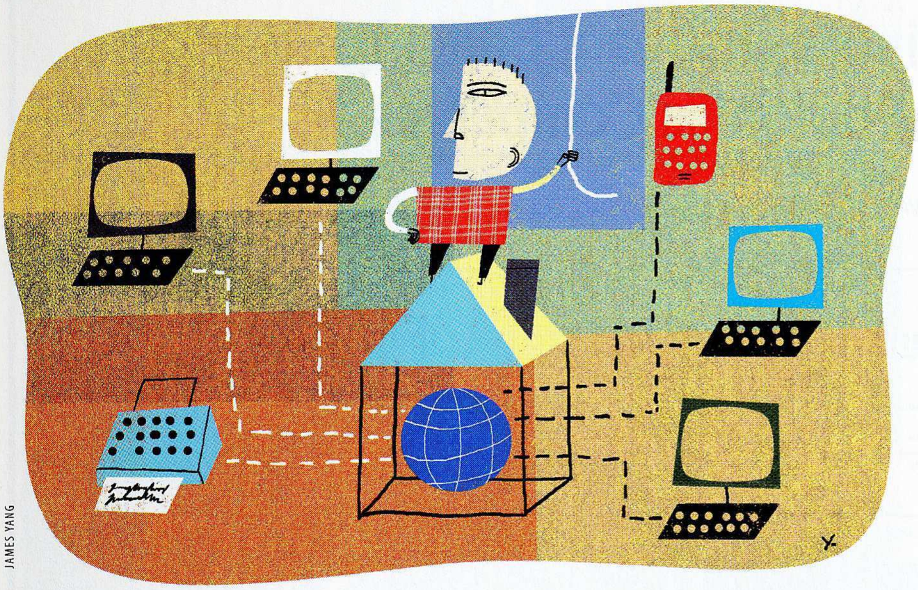
Trees headed for the market from ArborGen include genetically modified hardwoods like poplar and sweet gum, used for high-quality paper products. ArborGen also believes it can stock plantations of modified pine and eucalyptus trees, workhorse species that can be used for building products or ordinary paper pulp. "I think the first product we put out will be a very important product, not only for technical performance, but in how we are perceived," says Maud Hinchee, the newly hired chief technology officer at ArborGen. "We want to make sure that when we launch a product, it will be perceived by the public as being safe and beneficial."

Environmental groups are already concerned. "There's a big difference between genetically modified crop plants and trees, in the sense that trees are perennial and live a long time," says Jane Rissler of the Union of Concerned Scientists. "Will tree roots pump out a genetically modified toxin for years and years? And what happens if you have insect-resistant trees spreading genes to relatives that live outside, in unmanaged ecosystems? There are many ecological issues with [modified] trees that need to be carefully studied."

To prepare itself for the emerging debates over biotech-tree safety, the industry has joined with the state of North Carolina—a center for both biotech research and the $3.2 billion forest-products industry—to form the Institute of Forest Biotechnology, a Research Triangle Park, NC-based think tank chartered to promote the societal benefits of modified trees and address environmental concerns. Steven Burke, the institute's director, argues fast-growing, efficient stands of modified trees could better serve the needs of the paper and wood industries while reducing chemical pollution from papermaking and leaving more wild forests alone.

The think tank will have a lot to think about: ArborGen isn't the only group developing biotech trees *(see table at left)*. In the past decade, the USDA has given 136 approvals—most in the last three years—for small outdoor test plots, some of which include fruit trees. David Wheat of the Bowditch Group, a Boston-based agricultural technology consulting firm, says work is also progressing in labs and testing fields as far flung as Canada, Australia and South Africa. Genetically modified trees, he says, "are reaching the point of practical application. They'll enter the commercial sphere gradually, because of regulatory and public concerns, but also because you don't plant a million [hectares] the first year out. But, he added, "I don't think we are going to see genetically engineered *Time* magazine pages until 10 years from now."

—Kathryn Brown



JAMES YANG

Sharing the (Broadband) Wealth

HOME NETWORKING | For years, the computer industry has tried and failed to interest consumers in home networking. The major obstacles—high costs, the lack of standards, and difficult-to-use technology—have now been largely overcome, but one major sticking point remains: the lack of buyer incentive. With today's under-$100 prices on printers and scanners, peripheral sharing is not a pressing need; files can be shared via e-mail, and few households need to share applications. There is one commodity, however, that is in high demand: Internet bandwidth.

Companies have started to ship new "gateway" devices that let housemates share bandwidth—and, in many cases, multiple phone lines—throughout their homes. Most of today's products from vendors such as Alcatel, 2Wire and ShareGate are designed for digital subscriber line, or DSL, connections, but cable-modem gateways are on the way from Motorola and others.

Bandwidth sharing is automatic—if one user is surfing the Web, and a second logs on to another linked computer, each receives half the available bandwidth. When one user logs off, full bandwidth is restored to the other user. With most gateways, you can also activate up to four new voice lines and easily reassign them when phones are added or moved around the house. A portion of the overall bandwidth is allotted for each virtual phone line in use, but the bandwidth is usually made available for Internet access again when the phones are hung up.

While over a dozen gateways should be available by year's end, it may take longer before the technology becomes widely used. The vendors of gateway products promise easy installations and remote configuration, theoretically eliminating the need to send a technician to the home. Even in a simplified home version, however, networking is complicated, and major broadband service providers have so far refused to offer technical support for anything beyond the modem itself. "Closer coordination with the broadband [service providers] will be key to making home networking take off," says Joseph Laszlo, senior analyst for broadband and wireless at Jupiter Research.

Gateways may do more than help distribute voice and data. Some devices offer home automation features that let you remotely turn on the alarm or set the thermostat. Wireless gateway vendors, meanwhile, hope to link up to Web-enabled cell phones, handhelds and other smart appliances, letting them share Internet bandwidth and access to peripherals.

—**Becky Waring**

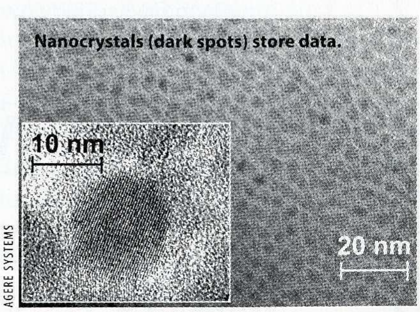
Shrinking Chips

HARDWARE | For handheld products such as cell phones and digital cameras to get smaller, manufacturers must also shrink the devices' silicon memory chips. But the tinier the chip, the more vulnerable it is to leaking the charge that stores data. Now researchers at the California Institute of Technology and Allentown, PA-based Agere Systems say they've devised a new—and inexpensive—way of fabricating leak-resistant memory that could provide chips with much greater storage capacity.

The technique applies to flash memory, which retains information even after power is turned off. As a conventional flash memory chip gets smaller, a critical layer of insulation that protects data stored as electric charges becomes thinner, risking charge leaks.

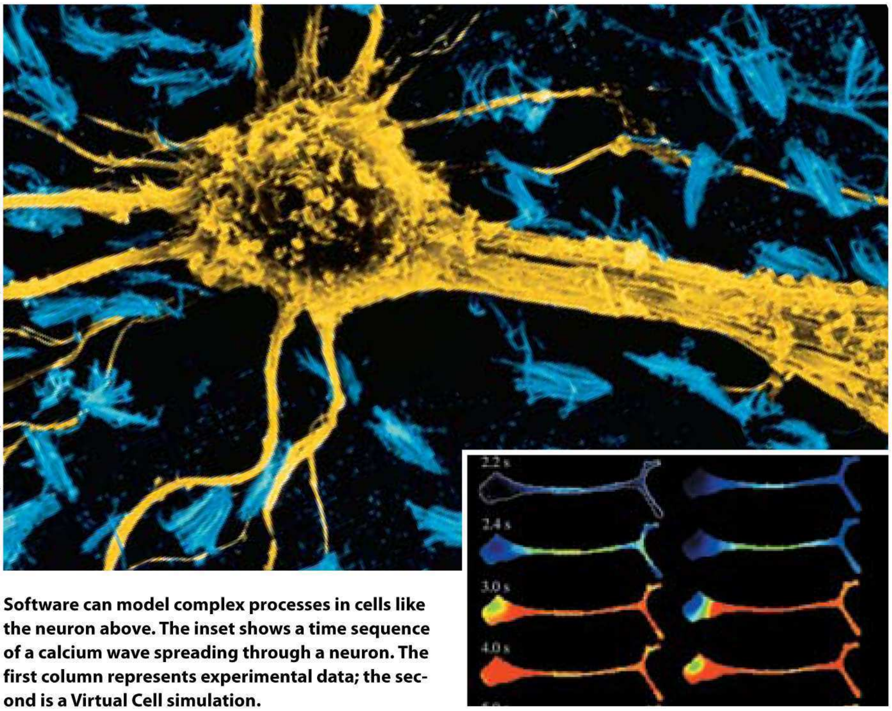
Electrical engineer Jan De Blauwe of Agere, applied physics and materials science professor Harry Atwater of Caltech and their colleagues have overcome this problem by creating a method for storing charges in a group of silicon nanocrystals grown and insulated individually at low cost. If one crystal fails, it doesn't affect the information saved. "And because the charge storage is more robust," says De Blauwe, "you can reduce the thickness of the insulating layer."

Sandip Tiwari of Cornell University's Nanofabrication Facility says the new technique is promising. "If reproducible, it could lead to some important improvements as we scale device structures to smaller dimensions," he says. Theoretically, it could also allow flash memory manufacturers to pack 100 times more memory onto existing silicon chips. —**Tracy Staedter**



Nanocrystals (dark spots) store data.

AGERE SYSTEMS



PHOTOTAKE (NEURON); LESLIE LOEW (INSET)

Software can model complex processes in cells like the neuron above. The inset shows a time sequence of a calcium wave spreading through a neuron. The first column represents experimental data; the second is a Virtual Cell simulation.

Biology in Silico

Computer models could revolutionize drug development

Computers capable of mimicking life have long been the stuff of sci-fi nightmares—think *The Terminator* or *2001*'s HAL 9000. But for researchers struggling to make sense of vast amounts of new biological data, and for drug companies anxious to cut costs and speed development, having accurate computer simulations of living systems is still a dream. To make that dream come true, they are turning to "in silico biology," building computer models of the intricate processes that take place inside cells, organs, and even people. The ultimate goal: an entire organism modeled in silicon, allowing researchers to test new therapies much as engineers "fly" new airplane designs on supercomputers.

For more than a decade, medicinal chemists have tried to make drug discovery more "rational," using computers to simulate how, for example, a new drug molecule binds to a receptor. But today's computer models go far beyond that, taking advantage of data from areas ranging from genome sequencing to clinical trials to look at how a potential drug affects entire biological systems. Creating a "virtual cell" or, better yet, a "virtual heart patient" is still a work in progress, but even early models could begin to put a dent in the massive cost of developing new drugs.

According to industry figures, using traditional methods takes an average of $500 million and 15 years to develop and test a drug; in silico technologies could save at least $200 million and two to three years per drug, according to a recent PricewaterhouseCoopers report. One reason is that the drug-testing process—during which a compound is studied in animals, and then in humans—is far from efficient. According to statistics from the U.S. Food and Drug Administration, human trials fail for 70 to 75 percent of drugs that enter them. Some trials fail just because the dose is wrong.

To drive home just how inefficient such a trial-and-error approach can be, Thomas Paterson, chief scientific officer of Menlo Park, CA-based Entelos, makes this comparison: "If Boeing developed aircraft the way the pharmaceutical industry develops drugs, they would develop 10 very different aircraft, fly them, and the one that didn't crash would be the one they sell to United Airlines." So companies like Entelos and Princeton, NJ's Physiome Sciences are developing computer models that can be used both to identify molecular targets for new drugs and also to simulate clinical trials. For example, the Leverkusen, Germany-based pharmaceutical giant Bayer is using one of Entelos's models to evaluate a potential drug for asthmatics, testing a variety of patient types and treatment regimens on the computer.

The Internet could become a critical tool in developing such models, allowing researchers to collaborate around the world. So Physiome has partnered with the Bioengineering Research Group at New Zealand's University of Auckland to develop an open-standard computer language for biological modeling. That language, called cellML, is available at www.cellml.org. The idea, says Physiome executive vice president Thomas Colatsky, is that researchers will be able to build models in a common format and share those models via the Web.

Still, many believe it's premature for drug researchers to begin setting their lab rats free. Leslie Loew, a member of the cellML advisory board and the director of the Center for Biomedical Imaging Technology at the University of Connecticut Health Center, has made his own modeling tool kit accessible on the Web: the Virtual Cell, at www.nrcam.uchc.edu. Within five years, Loew predicts, modeling software will be a routine, perhaps indispensable, tool for anybody who seeks to understand how cells work. But, Loew cautions, it will still take many years to build complete, highly accurate models of whole cells, let alone organs or entire organisms. And bioinformatics professor Masaru Tomita—whose group at Keio University in Fujisawa, Japan, has put its E-Cell simulation software on the Web at www.e-cell.org—agrees. While E-Cell does aim to model whole cells and, eventually, interactions among a dozen or fewer cells, Tomita says modeling anything more complex "would be a whole different ball game." —**Rebecca Zacks**

IP's *Bleak House*

HAVE YOU EVER READ BLEAK *House*, the Dickens classic in which lawyers fight incessantly over a disputed inheritance until they gobble it all up in legal fees? With the U.S. Patent Office now handing out a staggering number of patents on various methods of doing business—as opposed to actual inventions—it looks like we're in for a modern-day remake. In today's version of *Jarndyce v. Jarndyce* (the interminable *Bleak House* proceeding), lawyers haggle over these absurdly vague and broad patents, squandering not just money but the very innovation the patent system was established to stimulate.

For a preview of *Bleak House 2: The Patent Years*, consider last November's appeals ruling in the case *Interactive Gift Express Inc. v. CompuServe et al*—a.k.a. the fight over U.S. Patent No. 4,528,643, "System for Reproducing Information in Material Objects at a Point of Sale Location." One of the first patent infringement claims involving an e-commerce business method to reach the top (the U.S. Court of Appeals for the Federal Circuit), this case has seen almost as many judicial twists as the presidential election. I thought we had reached a sane solution in 1998, when a lower court took a narrow interpretation of the patent's scope. But now, after several years of litigation that has tied up time and resources at more than 40 e-commerce companies, the appellate court has overturned the lower court on *all five contested claims*. What's more, instead of definitively reversing the decision, it has remanded the case for—you guessed it—more legal proceedings.

The question in this case is whether the patent gives E-Data of Greenwich, CT (formerly Interactive Gift Express), an exclusive right to the underlying "method" of selling downloadable material—music, software, books, films and more—over the Internet. E-Data's lawyers claim it does. They contend CompuServe (now part of America Online), Ziff Davis Publishing, Broderbund, Intuit, Waldenbooks, and other defendants—and by inference thousands of additional online businesses—infringe the patent whenever they sell downloadable material.

The result has been a judicial mess. But, to be fair, you can't blame the courts alone. Like many other business-method patents, E-Data's is so enticingly broad, so vaguely worded and so potentially lucrative it's little wonder a dizzying succession of lawyers, financiers and small-time entrepreneurs want to cash in on it. (For the hairsplitting legalese of the appellate ruling and related documents, see www.patents.com/ige.htm.)

It all started in 1983, when electrical engineer Charles Freeny envisioned a networked computer system that could allow store owners to offer customers downloaded copies of products like books or sheet music. Freeny never tried to build such a system. Instead, he patented his idea and, finding little interest in it, sold the patent to a speculator in 1989.

After changing hands again, the Freeny patent resurfaced dramatically in 1996. That's when new owner E-Data sent a letter to 75,000 companies threatening to sue if they didn't pony up licensing fees. The campaign landed notable licensing agreements with IBM, Adobe and others. But it also sparked outrage, paving the way for the current litigation, which has lawyers on both sides poring over the ambiguous text like alchemists hoping to spin gold from pig iron. Consider the phrase "point of sale location." The case has hinged in part on whether this can include people's homes, or just stores. Now, as the case returns to the courtroom, the judge has been ordered to let the participants dive deeper into the quagmire by considering whether the patent covers downloading data to a hard disk or only to some more tangible format like CD-ROM. (More legalistic alchemy, since the patent itself mentions neither device specifically.)

Business-method patents will likely stymie the very innovation that the patent system was designed to stimulate.

As this case shows clearly, business-method patents tend to be so, well, "fuzzy" they are difficult, if not impossible, to adjudicate by wrangling over such particulars. Rather than affording a limited monopoly on a new, improved design for a mousetrap or vacuum cleaner, as patents are reasonably intended to do, method patents confer a monopoly on a broad *concept*—the equivalent of inventing the idea of "catching mice with a trap" or "using a suction device to clean carpets."

This point is fundamental. Because such patents are, by their nature, nearly impossible for competitors to work around, they are likely to stymie innovation rather than spur it. It's all the more worrisome when you consider that this case is the tip of an enormous iceberg. Thousands of broad business-method patents have issued since Freeny's, and the Patent Office says it now receives some 2,500 such applications annually in the software field alone. Which means that until Congress can come to its senses and bring the long-running IP *Bleak House* serial to an end, we're facing a scenario only a patent attorney could possibly love. ◊

A perfectly balanced technology platform

INITIAL PUBLIC OFFERINGS

TRANSMETA CORPORATION **$273 million** Initial Public Offering Joint Lead Manager November 2000	endwave **$84 million** Initial Public Offering Lead Manager October 2000	NCIPHER **£108 million** Initial Public Offering Sponsor, Global Coordinator and Bookrunner October 2000	DOCENT **$101 million** Initial Public Offering Lead Manager September 2000	VASTERA **$97 million** Initial Public Offering Lead Manager September 2000
EVOLVE. **$52 million** Initial Public Offering Co-Lead Manager August 2000	DIMENSION DATA **£1.07 billion** Initial Public Offering Joint Global Coordinator and Bookrunner July 2000	TRIPATH **$51 million** Initial Public Offering Co-Lead Manager July 2000	ValiCert Securing e-Transactions **$46 million** Initial Public Offering Lead Manager July 2000	webex **$56 million** Initial Public Offering Co-Lead Manager July 2000
Dialog Semiconductor **$462 million** NASDAQ Initial Public Offering EASDAQ / Neuer Markt Secondary Offering Joint Lead Manager and Joint Bookrunner June 2000	Mobility Electronics **$55 million** Initial Public Offering Lead Manager June 2000	Autonomy **$273 million** NASDAQ Initial Public Offering EASDAQ Secondary Offering Sole Lead Manager and Bookrunner May 2000	pixelworks **$66 million** Initial Public Offering Co-Lead Manager May 2000	STANFORD MICRODEVICES **$55 million** Initial Public Offering Lead Manager May 2000
i3 Mobile **$90 million** Initial Public Offering Lead Manager April 2000	EPRISE mind your content **$69 million** Initial Public Offering Lead Manager March 2000	faimarket **$98 million** Initial Public Offering Lead Manager March 2000	Infineon technologies **€6.1 billion** Initial Public Offering Joint Global Coordinator and Joint Bookrunner March 2000	LYCOS Europe SHAPING THE FUTURE OF THE INTERNET **€700 million** Initial Public Offering Joint Lead Manager and Joint Bookrunner March 2000

Deutsche Banc Alex. Brown

MERGERS AND ACQUISITIONS

Bluestone Software **$525 million** Has agreed to be acquired by Hewlett-Packard Pending	manugistics **$358 million** Has acquired Talus Solutions December 2000	element 14 **$594 million** Has been acquired by Broadcom November 2000	LYCOS Europe **€961 million** Has acquired Spray Network October 2000	SMALLWORLD **$212 million** Has been acquired by GE Powersystems October 2000
CDNOW **$134 million** Has been acquired by Bertelsmann August 2000	NTT Communications **$5.5 billion** Has acquired Verio August 2000	VASTERA **Undisclosed** Strategic alliance and merger with Ford Motor's U.S. customs operations August 2000	DIGITAL INSIGHT **$140 million** Has acquired AnyTime Access July 2000	NATURAL MicroSystems **$155 million** Has acquired InnoMediaLogic July 2000
ASK PROXIMA **$518 million** Has been acquired by InFocus Corporation June 2000	Peregrine Systems **$2.0 billion** Has acquired Harbinger Corporation June 2000	Buhrmann **Undisclosed** Sale of Information Systems Division to Specialist Holdings Group May 2000	connecta **$1.6 billion** Merger with Information Highway AB May 2000	C-PORT **$430 million** Has been acquired by Motorola May 2000
MANDATOR **$1.4 billion** Merger with Cell Network AB April 2000	cnet **$736 million** Has acquired mySimon, Inc. March 2000	Maker Communications, Inc. **$1.4 billion** Has been acquired by Conexant Systems March 2000	yesmail.com **$721 million** Has been acquired by CMGI March 2000	flycast **$2.5 billion** Has been acquired by CMGI January 2000

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GUTENBERG'S PRINTING PRESS NEEDED PAPER TO MAKE A REVOLUTION.
THE CLUNKY E-BOOK NEEDS E-PAPER.
AND IT'S ON THE WAY. **BY CHARLES C. MANN**

Electronic Paper
Turns the Page

PHOTOGRAPHS BY JOHN SOARES

With PowerPoint presentations, Palm Pilot-beaming executives and cell phones trilling in the audience, last November's e-Book World seemed typical of the hundreds of business-tech gatherings held every year. But it wasn't. In fact, it was the first conference devoted solely to the forthcoming transformation of the book world by digital technology. Hundreds of people from around the world paid as much as $995 to hear some of the most influential editors and publishers in the United States forecast radical changes in the writing, distribution and reading of printed material.

During the two-day conference, the agents, authors, technologists and publishers in attendance repeatedly heard that the day of ordinary books, magazines and newspapers was almost over. The key cause of this demise, attendees were told, will be the newly developed e-book. So powerful will be the onrushing wave of e-books, confidently predicted Dick Brass, Microsoft vice president of technology development, that "the last paper edition of the *New York Times* will appear in 2018."

The new e-books were on display in the exhibit space. They were, for the most part, keyboardless computers, each about the size of a paperback. Visitors gingerly tapped the screen or thumbed a button to "turn" the pages on these gray boxes; with some models, readers could "bookmark" favorite passages. Don't be fooled by their unprepossessing appearance, conference organizer and author Michael Wolff warned in his keynote speech. "The e-book," he proclaimed, "is the most significant development in the book business since the advent of the paperback."

Maybe. Digital technology and books, magazines and newspapers are certainly going to collide, just as Wolff said. And, as he also said, the results will have an enormous social and cultural impact. But the key invention will not be the electronic book—at least not the gray boxes on exhibit at e-Book World. Instead, it will be a development that not a single speaker at the conference addressed—a product that not one of the companies in the exhibit displayed. Although the collective imagination of the publishing industry has been captured by the current generation of electronic books, the technology that is most likely to transform reading and writing will be electronic paper.

A handful of leading technology companies are vying to create the first practical electronic paper—a digital display thin and flexible enough to roll into a tube or fold up like a map, yet cheap enough to be sold in reams or wired with a few hundred other screens into the spine of a notebook. Recent progress has been so rapid some researchers believe that in just a few years this novel kind of display could replace paper in many situations, leading to the creation of books, magazines and newspapers made from sheets of wired plastic.

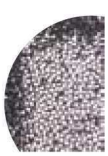
"We're talking about something that would be the first real change to the technology of the book in 500 years," says Paul Drzaic, technology director at E Ink, a startup in Cambridge, MA that unveiled an initial prototype of e-paper late last year. "You have to be aware of the implications. We're not comparing ourselves to Gutenberg in any way, but it's incredible to think that we could be in a time that would be mentioned in the same breath."

Historians have long argued that the technology needed to create a printing press with movable type had been in Europe for more than a century before the 1440s, when Johann Gutenberg and several other craftsmen in the German city of Mainz set up the first composing rooms. "But the important thing was missing," historians Lucien Febvre and Henri-Jean Martin wrote in *The Coming of the Book*, a classic account from 1958. "It would have been impossible to invent printing had it not been for the impetus given by paper, which [only] came into general use by the late 14th century."

Before paper—a Chinese invention, sent to Europe by the Arabs—Europeans wrote manuscripts on vellum and parchment, which were made from, respectively, lambskin and sheepskin. (The terms are inexact; sometimes goats or calves provided the raw material.) Although animal hides could be shaved into sheets of amazing thinness, they

DEANNA HORVATH/XEROX PARC (GYRICON BALLS); WEBB CHAPPELL (JOSEPH JACOBSON)

The Evolution of e-Paper



1975

Xerox PARC's Nick Sheridon begins work on electronic ink, using small rotating spheres; he calls the system Gyricon.

Sheridon makes a crude prototype of Gyricon, writing out the "X" in Xerox.

1976-77

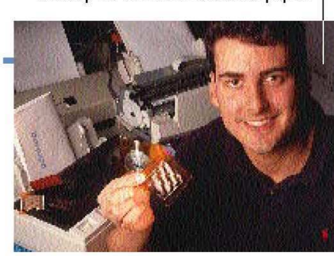
Hideki Shirakawa, Alan MacDiarmid and Alan Heeger publish reports describing electrically conducting plastics.

1977

Xerox takes Sheridon off the Gyricon project.

1996

Joseph Jacobson joins MIT's Media Lab and begins work to develop his version of electronic paper.



were expensive, did not take ink well and were generally too brittle to pass through a press. Even if skins could be printed on, large editions would necessitate mass slaughter: the historian Aloys Ruppel once calculated that stamping out a hundred copies of the Gutenberg Bible on vellum would have consumed 15,000 lambs. Only when paper became widespread on the Continent did printed books become technically and economically feasible.

The history of electronic paper is shorter and less colorful, but as a historian might say it is not devoid of incident. Perhaps the first researcher to consider electronic paper seriously was Nick Sheridon, a physicist at Xerox's Palo Alto Research Center (PARC), birthplace of the mouse-and-windows computer interface. In 1975, when Sheridon joined PARC, he noticed a paradox. His colleagues at PARC were excitedly imagining a future world in which printed books and magazines would be supplanted by computer displays. But the monitors actually used at PARC—bulky devices with green-and-white displays—had such poor contrast that researchers often had to draw their blinds to see what they were doing. "A *Newsweek* or *Time* that was replaced by a flat version of one of those computer monitors would have been almost unreadable," Sheridon says. "I thought, I guess, that instead of replacing paper with the monitor, it might be smarter to replace the monitor with paper."

Quickly he came up with a possible means, which he called Gyricon, from the Greek for "rotating image." In its present incarnation, Gyricon is a transparent silicone-rubber sheet in which are embedded thousands of tiny plastic spheres, each smaller in diameter than a human hair. Each sphere has a black half, which carries a very small static electricity charge, and a white half, which is electrically neutral. If an electric field comes near the spheres, it attracts or repels their black halves, causing the spheres to rotate. If the white halves end up tilting toward the upper side of the rubber sheet, the viewer sees white dots; if the black halves face the viewer, the dots are black. Placing a Gyricon sheet between the same types of circuit that control the pixels on a laptop screen will arrange the spheres in much the same way, creating a black-and-white image.

Soon Sheridon had a crude working model. Resembling a country cousin of the Etch A Sketch, it could produce an X for Xerox. He thought it would be ready for the market around 1985, if he could just lick a few practical problems. Foremost among them was a manufacturing question: while Sheridon had devised a means of fabricating the little balls, it did not yield uniform spheres; he found himself poking through the tiny globes, looking for good ones.

Another, more daunting, problem lay ahead. The rubber sheet had to be controlled, or addressed, by the electrodes on a circuit board, and all known flat-circuit display boards were stiff and inflexible—totally unlike paper. Worse, they were expensive. Indeed, such circuitry was (and is) the reason laptops cost more than regular computers. As a result, the Gyricon prototype was more like a rigid, expensive electronic clipboard than a bendable, cheap sheet of paper. Unable to see much value in research that seemed to be producing a pricey black-and-white-only substitute for laptop screens, Xerox pulled Sheridon away from e-paper in 1977.

Years later, in the mid-1990s, a young physicist named Joseph Jacobson joined the Media Lab at MIT *(see "Print Your Next PC,"* TR *November/December 2000)*. He, too, had been thinking about electronic paper. With two students, he set about duplicating Sheridon's work. But the MIT group, too, couldn't make the black-and-white balls come out right. Instead, they came up with a variant of the idea. Like Sheridon, the MIT group uses a thin sheet of rubbery plastic crammed full of tiny spheres. But these spheres are not solid; they are hollow capsules filled with colored oil and small, electrically charged chips of titanium dioxide paint. When a current passes near the sheet, it pushes or pulls the chips up or down, coloring the top of the capsules, which thus act like pixels on a monitor. In 1997 Jacobson and his two students co-founded E Ink, which

"I THOUGHT THAT INSTEAD OF REPLACING PAPER WITH THE MONITOR, IT MIGHT BE SMARTER TO REPLACE THE MONITOR WITH PAPER."

1997

Lucent Technologies' Bell Labs reports fabricating transistors made from organic polymers.

April Jacobson and two students co-found E Ink to commercialize electronic paper.

1999

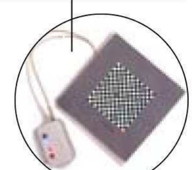
June Xerox and 3M announce collaboration to develop and make e-paper.

October E Ink and Lucent partner to develop flexible, electronic displays utilizing e-ink and organic electronics.

2000

November E Ink/Lucent display the first electronic paper made from e-ink and plastic transistors.

December Xerox spins Gyricon off to commercialize electronic paper.



DEANNA HORVATH/XEROX PARC (GYRICON SHEET); JOHN SOARES (E-PAPER PROTOTYPE)

has attracted more than $50 million in venture capital.

Meanwhile, Xerox had interested itself again in its own technology; Sheridon was put back on the e-paper trail in the mid-1990s. He refined the manufacturing process, and Xerox signed a deal with 3M to manufacture Gyricon sheets in large quantities. By 1999 IBM was also in the fray, and Philips was rumored to be sniffing around the e-paper market. However, despite being founded more than 20 years after Sheridon began work at Xerox, E Ink won the first leg of the race to market. Its initial product, introduced in May 1999, was an in-store display sign for J. C. Penney that could change messages to shoppers. But this "e-placard" lacked a vital characteristic of paper: it couldn't bend, because the capsules needed to be addressed by a rigid circuit board. Its inflexibility, however, was being addressed from an entirely different direction.

In some sense, Sheridon was too early. Around the time he developed the Gyricon balls—the "ink," so to speak, for electronic paper—other researchers were discovering the principles that eventually would make possible the electronics critical to making the paper itself. But their work came to fruition well after Xerox initially abandoned the Gyricon. And it came as a by-product of an explosion of new research into a seemingly unrelated subject: electrically conducting plastic.

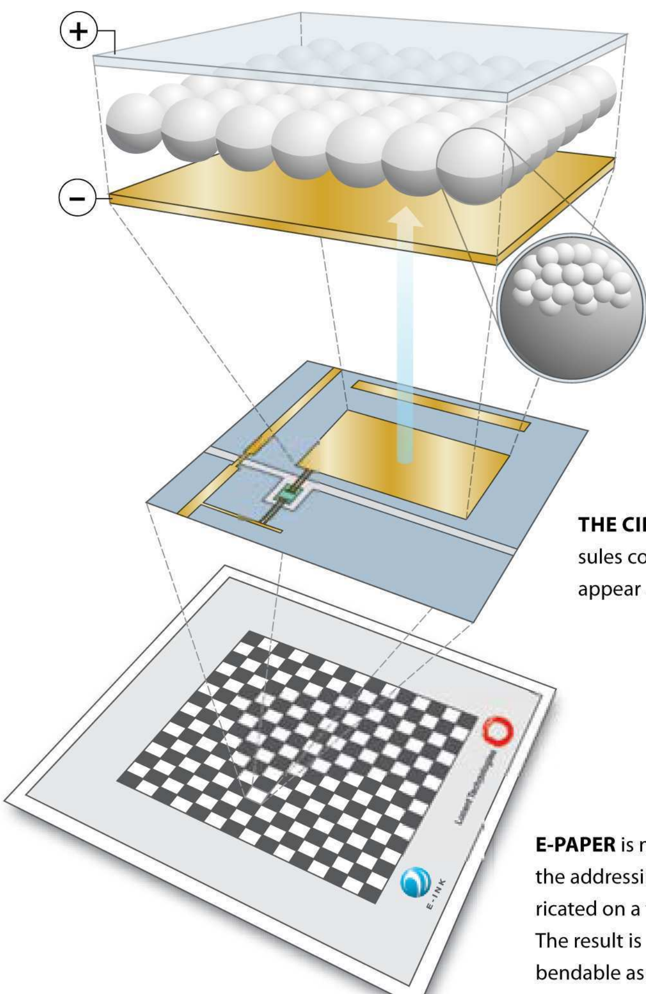
Long known as an insulator, plastic has only recently become known as an electrical conductor. Indeed, the three men most responsible for the discovery of plastic's conducting properties won the Nobel Prize for chemistry last December. The field they created is generically known as "organic" electronics because the plastics that conduct electricity are based on the kind of carbon-containing molecules that characterize life, even if these particular substances are not found in living beings. Plastic will probably always conduct electricity more slowly and inefficiently than inorganic materials like silicon and copper, researchers say. But plastic is fast enough for many electronics applications—and lighter, cheaper, and more flexible than silicon and copper will ever be.

Around the world, chemists and physicists in academia and industry are learning how to create organic circuits in continuous processes, printing or spraying or stamping circuits onto rolls of plastic in a process analogous to printing a newspaper. Despite that analogy, however, the "terrific" idea of e-paper "never occurred" to the discoverers of organic electronics, says Alan Heeger of the University of California, Santa Barbara, one of last year's Nobelists. But the connection was obvious to researchers involved with electronic inks, like Sheridon and Drzaic at E Ink.

In 1999, E Ink and Lucent Technologies agreed to spend a year trying to learn whether they could actually create the first workable model of true electronic paper. Lucent used its expertise in organic semiconductors to rubber-stamp the addressing circuitry onto a sheet of transparent Mylar. In this innovative process, a thin film of gold is sprayed onto the Mylar; the stamp, which has thin ridges that are coated in a special liquid resist (a chemically protective material) imprints dark lines across the gold; a solvent then washes away the gold, except for the lines shielded by the resist. When E Ink placed a layer of electronic ink on top, the sheet, following its electronic instructions, switched back and forth between a checkerboard pattern and the corporate symbols for E Ink and Lucent. "A world first for that kind of display," said Pierre Wiltzius, head of condensed-matter research at Bell Labs, the research arm of Lucent, when he announced the result last November.

Printing an e-Page

E Ink and Lucent Technologies have made a crude prototype of electronic paper.



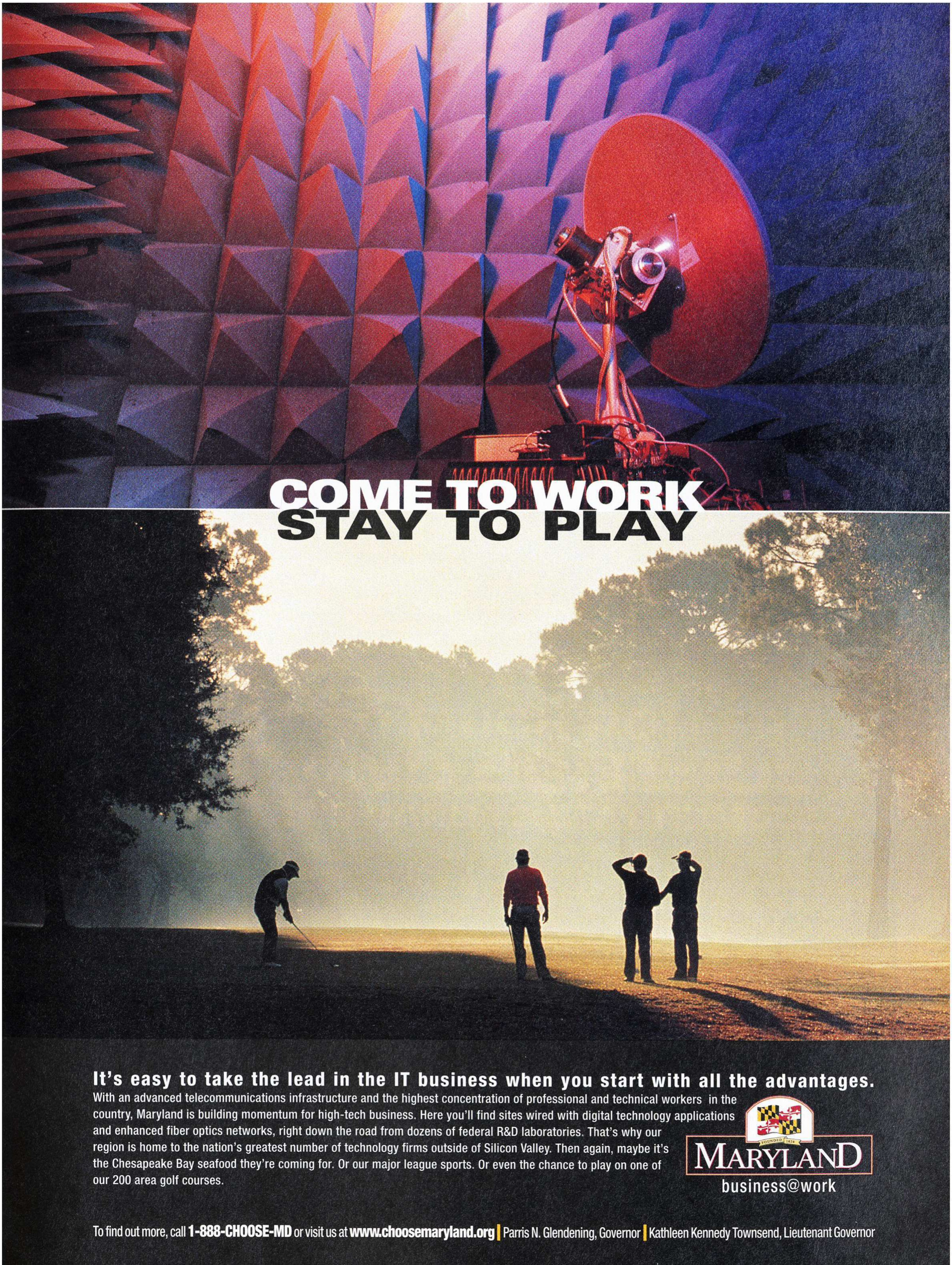
THE INK consists of tiny spheres, which are filled with electrically charged white particles suspended in a light oil.

THE WHITE PARTICLES are oriented within each sphere by an electrostatic charge.

THE CIRCUITRY underlying the capsules controls whether the spheres appear as white or black pixels.

E-PAPER is made of the electronic ink and the addressing circuitry, which can be fabricated on a thin, flexible plastic substrate. The result is a display that is as thin and bendable as a sheet of paper.

RON CARBONI; SOURCE: LUCENT TECHNOLOGIES



COME TO WORK
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With an advanced telecommunications infrastructure and the highest concentration of professional and technical workers in the country, Maryland is building momentum for high-tech business. Here you'll find sites wired with digital technology applications and enhanced fiber optics networks, right down the road from dozens of federal R&D laboratories. That's why our region is home to the nation's greatest number of technology firms outside of Silicon Valley. Then again, maybe it's the Chesapeake Bay seafood they're coming for. Or our major league sports. Or even the chance to play on one of our 200 area golf courses.
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In December, financially troubled Xerox spun off Gyricon as an independent subsidiary. "E-paper is still something we're considering," a spokesperson says. "But right now we want to look at networked in-store signage. Did you know that's a $14 billion market?"

Nonetheless, Wiltzius says, "electronic paper is what captures the imagination." In three to five years, he thinks, the E Ink/Lucent team might have e-paper with a resolution equivalent to about 100 dots per inch. "That's a little better than a [Palm] Pilot," he says. "We already have the viewing angle down—you can read across a much wider range of angles. And then there's the issue of color, which I think can be done." He ticks off challenges: durability, reliability, printing registration. "There's some good work to do before this paper is ready to change the world," he says.

The book of the future, e-paper researchers like to say, will look just like a regular book. It will have a hard cover and a spine and several hundred thin, white, flexible pages. But the spine will be filled with electronic circuitry and a wireless data port and maybe a stylus; the pages will be electronic displays. Readers will open the cover and—here the vision gets a little fanciful—be confronted with a list of the works contained in the book, arranged by title, author or subject matter. Because this is 10 or more years from now, data-storage devices will have shrunk even further, and thus embedded in the spine of this single volume may be a hundred novels, even a thousand, all downloaded through the data port. The reader may tap the name "Charles Darwin" and be offered a list of works ranging from the *The Voyage of the Beagle* to the *Origin of Species.*

After the reader selects the *Origin* with the stylus, the text swims noiselessly onto the empty pages of the volume. Tap a footnote with the stylus, and the appropriate text appears in a window on the bottom of the page. Does that book contain a reference to another work by Darwin? Scribble a request on the inside cover and jump onto the Net to grab a copy. Scientific texts could be continually altered to keep pace with research.

Some of this will be possible with conventional e-books, of course. But electronic paper, which is reflective, is inherently more readable than backlighted computer displays: even the crude prototypes made so far are legible at a greater angle and in brighter sunlight than most computer monitors. Not only that, conventional e-books sacrifice many of the best design features of books—the possibility of flipping back and forth between pages, the capacity to negotiate a text by remembering the physical placement of favored passages, and the chance to underline passages and mark pages. In addition, electronic paper could be so inexpensive that a few hundred sheets of it in a book could cost less than most laptop screens. Like the printing press before Gutenberg, the e-book will need paper to become important in most people's lives.

Newspapers, too, may be little changed in appearance but greatly altered in function by the advent of electronic paper. Robert Steinbugler, an IBM designer, won a 1999 Industrial Design Excellence Award from the Industrial Designers Society of America for a mock-up of the newspaper of tomorrow. It looked like a thin version of the *New York Times*, except that the loose pages were bound to an aluminum spine mounted on a hard pad, slightly larger than the e-pages, which contained command buttons. In Steinbugler's design, the spine and pad held a battery, a data port and enough memory to store hundreds of newspapers. Future readers could flip through the sheets, which had the serendipitously jumbled-together articles of real newspapers, but switch between sections by clicking buttons; with a jab from the thumb, the news would vanish from the page and be replaced by the sports. The effort wasn't merely conceptual; IBM is gearing up its own e-paper drive, using another variant of organic circuitry. "E-paper is the key," Steinbugler says. "I always say that the last person to enjoy reading on a stiff tablet was Moses."

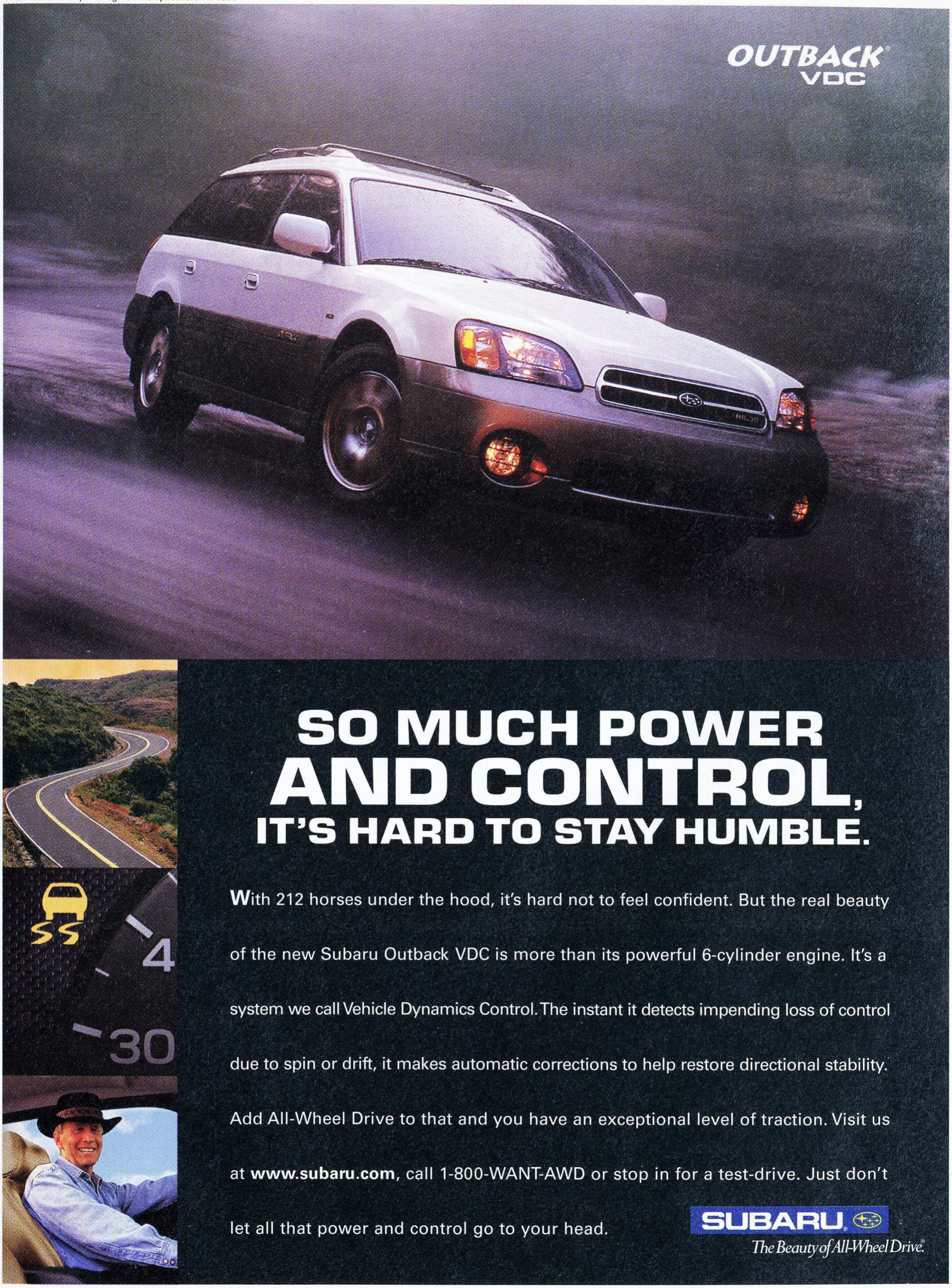
Moses may be an appropriate reference, Steinbugler suggests, because the cultural consequences of e-paper could "be Biblical in proportion." If every blank book is a potential library, will there continue to be a need for libraries? What will it mean to our experience of a novel if every other novel we have ever read can be called up from within its pages? If texts are instantly available on the Net, will authors and publishers continue to be able to make a living?

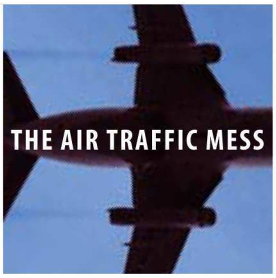
> "E-PAPER IS THE KEY. I ALWAYS SAY THAT THE LAST PERSON TO ENJOY READING ON A STIFF TABLET WAS MOSES."

The questions are "just endless," Sheridon acknowledges. "But I think this in the end will bring down the cost of books so much that it will make it possible for more people to have their own personal libraries." Without the costs of printing and distributing, book prices could fall without loss of income to writers and editors. Because an entire book reduces to a scatter of iron oxide particles on a computer hard drive, no text need ever go out of print—it can always sit there, whirling on the hard drive, until needed by the reader.

In response to a question, Sheridon talks about the Library of Alexandria, that ancient symbol of humankind's quest for total knowledge. Wanting all the books in the world, Ptolemy III searched every boat that entered the harbor for scrolls, copied any that he found, and returned the copies to the owners. For the last few years, floppy sheets of Gyricon have sat on Sheridon's desk. They can be erased and filled again with text more than a million times, he says. A book of such sheets could suffice for all the reading anyone does over a lifetime. In a way, every time Sheridon picks up a Gyricon sheet he is holding the prototype for the next Library of Alexandria. ◊

The ABC's of Safety: Air bags. Buckle up. Children in back.





BY DAVID TALBOT

The Digital Sky

TIRED OF FLIGHTS THAT ARE TWO HOURS LATE? THE FAA AND CARGO AIRLINES ARE BEGINNING TO TEST NEW GPS-BASED SYSTEMS AND DIGITAL DATALINKS THAT COULD HELP AVERT GRIDLOCK IN THE SKY. BUT—SURPRISE!—GENERAL IMPLEMENTATION WILL LIKELY BE DELAYED.

Every night between 11:30 p.m. and 2:30 a.m., nearly windowless jets with distinctive brown tails converge on Louisville, KY. One by one, about 90 aircraft in the United Parcel Service fleet land at the company's distribution hub flanking the Louisville airport, disgorge some 600,000 parcels, reload and hit the sky again. The system is remarkably efficient, and it has helped to keep UPS aloft as the nation's ninth largest airline.

But with the parcel delivery business expanding and the midnight skies over Louisville growing crowded, UPS is turning to new technology to compress arrivals and departures. In a radical experiment that may provide a glimpse into the future of air traffic control, UPS is embracing new satellite-based systems, hoping to wean itself off conventional radar-based technologies. Using the new digital tools, pilots would glance at cockpit displays showing their precise position, the positions of other UPS planes and a map of the airport and its runways—a display enabled by a combination of satellite positioning technology and digital datalinks between aircraft. Air traffic controllers would still run the show, but pilots would gain a tool to maintain more precise spacing on takeoff and landing.

ILLUSTRATION BY JAMES PORTO

IF THE UPS EXPERIMENT WORKS, says Dave Ford, a top Federal Aviation Administration official involved with the cargo airline's initiative, it could provide a model for enhancing safety and efficiency in the nation's overall air traffic control system. "One goal is to reduce runway incursions and accidents. We think this technology could help us in those areas. And we think there is a big link to efficiency," he says.

Efficiency is definitely the spur for UPS. "We believe we can increase our throughput with the same airport infrastructure," says company spokesman Ken Shapero. "If we can bring planes in faster or out faster, we can beat our competition." UPS predicts the technology will yield a 20 percent capacity jump at Louisville. A reduction of 20 to 30 seconds between some landings and takeoffs could shave about a half hour from the company's nightly sorting operation, a significant savings when your business hinges on delivering parcels on time. The numbers are so compelling that UPS is preparing to seek FAA approval later this year to use the system for approach and departure spacing at Louisville and is banding with other cargo carriers to push for even broader implementation.

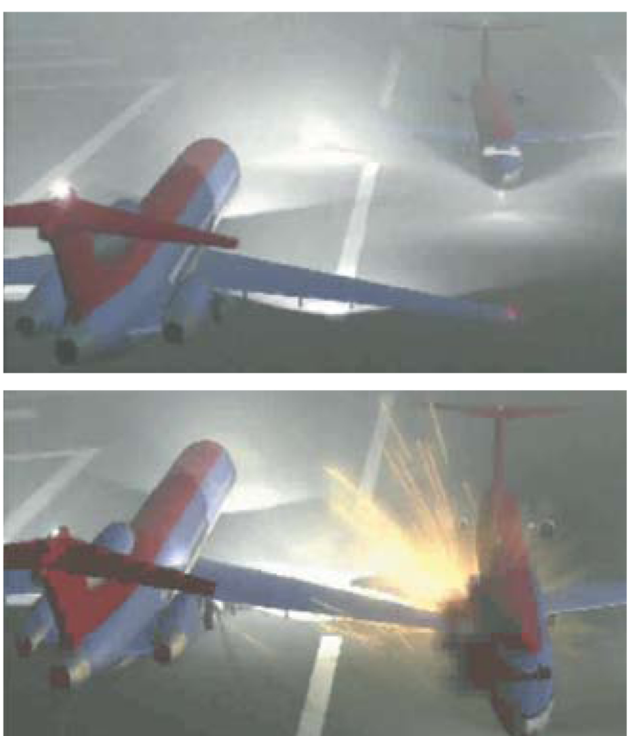
The question now is whether what's good for the cargo industry is also good for what aviation insiders jokingly call "self-loading cargo"—the traveling public. Can these satellite and datalink technologies help avert air-travel gridlock? In theory, they could keep airports functioning at full capacity in foggy weather, allow airplanes to land in pairs on closely spaced parallel runways, make possible more precise instrument landings and help airplanes avoid runway collisions. If this suite of technologies becomes widely available, "we in the [air traffic control] services industry may actually get ahead of the demand curve," says Frank Marchilena, executive vice president of air traffic control giant Raytheon.

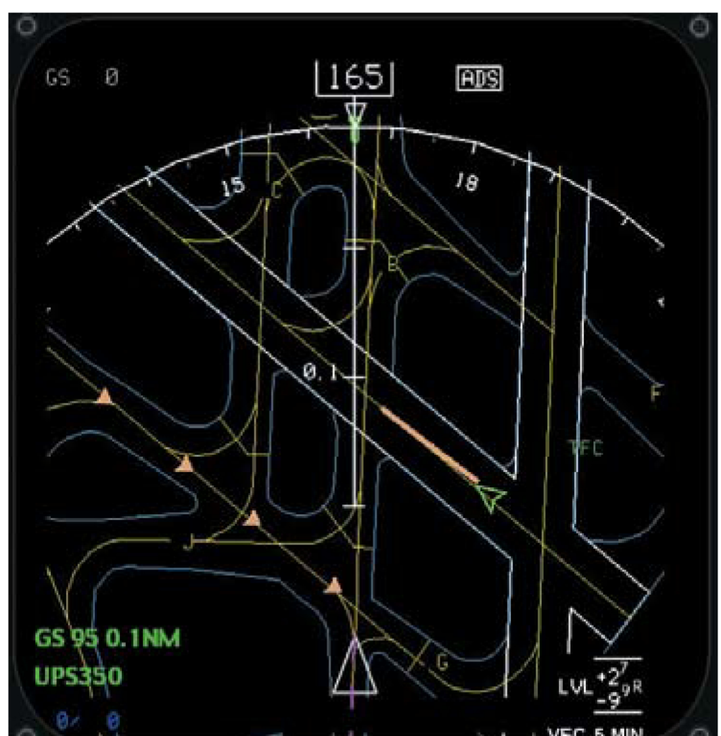
As any passenger at LaGuardia, O'Hare or Newark knows, the air traffic control system is lagging behind the demand curve now. Delays hit record levels in 1999 and 2000, and the problem promises to get worse. Last year, 670 million passengers flew in the United States; the FAA predicts 1 billion passengers will fly in 2010. According to FAA statistics, bad weather gets the lion's share of blame for the air traffic control-related delays. But weather causes widespread havoc in part because today's air traffic control systems are a patchwork of technologies built over the past half-century that are being stretched to the limit by the ever-increasing number of travelers. Radar technology has significantly improved since it was adapted for civilian air traffic

Satellite-based air traffic tools make business sense for the cargo industry. Can they also help "self-loading cargo"—the traveling public?

Averting Runway Disaster

When visibility is poor, taxiing pilots now rely on runway markers and controllers' orders. LEFT: This FAA computer re-creation depicts the Dec. 3, 1990, crash at Detroit Metropolitan Airport in which nine people were killed when a Northwest Airlines DC-9, its pilot disoriented by fog, parked in the path of an approaching Northwest Boeing 727. RIGHT: A proposed cockpit display—enabled by satellite position information and datalinks—shows runway traffic. Planes are triangles; a "needle nose" denotes high speed and stopping distance.





SUBSYSTEM TECHNOLOGIES (CRASH); UPS AVIATION TECHNOLOGIES (DISPLAY)

control after World War II, but the basic procedure remains the same. Controllers herd airplanes along a limited number of radar-monitored "highways" in the sky. When weather is bad, controllers close some of the highways, creating traffic jams. Bad weather also prompts controllers to enforce larger buffer distances between airplanes, increasing delays.

During the 1990s, the advent of Global Positioning System (GPS) technology—in which precise locations can be fixed by triangulating signals from any of 24 military satellites—promised a new approach. Using GPS, pilots can determine their exact locations without relying on ground-based navigation beacons. Over the past decade, a collaboration of several government-funded labs, including Bedford, MA-based MITRE and MIT's Lincoln Laboratory, developed a new way to continuously transmit digital GPS position information and other digital data among airplanes and controllers. With this network of digital information (known to insiders as ADS-B, or Automatic Dependent Surveillance-Broadcast), planes can continuously exchange data on location, speed, flight plan, aircraft size and type, number of passengers and weather.

The system can be thought of as the latest-generation phone lines and modems in an emerging "Aviation Internet"—one term being used to describe the increasing data flow among planes, controllers, ground crews and aircraft maintenance facilities. UPS Aviation Technologies is the only company that has developed cockpit displays certified by the FAA to receive and display information from this newly developed datalink, but others—including GE-Honeywell, Rockwell Collins and L-3 Communications—are working on their own systems.

Digital communication is only one element in the UPS system. After data from GPS and other sources reach an airplane, computers calculate relative positions of aircraft and their trajectories. Pilots glancing at cockpit displays and following computer-generated navigation instructions can precisely establish spacing between planes even in times of poor visibility. Add weather data, and the pilot can see and avoid storms *(see "Eyeing the Storm," p. 54)*. The same displays could give the pilot a detailed real-time map of an airport and positions of parked or taxiing airplanes. In the future, the suite of technologies could also provide ways for pilots to chart their own routes through the skies—a concept known as "free flight"—instead of staying inside pre-set "highways" directed by air traffic controllers *(see "Delayed Takeoff,"* TR *September/October 1999)*.

So far, the cargo airlines (including FedEx and Airborne Express) are the primary promoters of these satellite technologies. They hope that in addition to saving precious nighttime minutes, these tools will substitute for retrofitting their fleets with expensive mid-air collision warning devices that passenger aircraft already have—and cargo pilots want. Since passenger carriers have already installed warning devices, they are less motivated to develop the new tools. But another factor inhibits enthusiasm among the passenger airlines: an enormous existing radar-based infrastructure. This "installed base" is growing ever larger. The federal government is spending up to $600 million to build approximately 213 digital radar towers to upgrade the nation's air traffic control systems. The FAA and the airline industry are developing new tools to use refined radar data to achieve some of the efficiencies promised by satellite data. While it might be difficult to convince a passenger circling over LaGuardia airport, the fact remains that the current system works—and is safe.

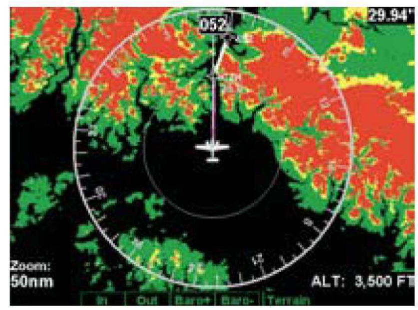
A fundamental shift to satellite-based tools would require a monumental effort to achieve consensus among pilots, controllers and regulators. How could consensus be achieved? In air traffic control, "things tend to be reactive rather than proactive, and that's probably what's going to happen here," says Jim Kuchar, associate professor of aeronautics and astronautics at MIT. "A systemwide change is either going to occur because of a major congestion problem, or because efforts like UPS make it more attractive. If UPS gets this thing working and it shows all these benefits, maybe others will say, 'we'll take another look at this.'"

That second look, however, may be slow in coming. Four years ago, United Airlines pilot Rocky Stone proposed using the new satellite-based technology to fight congestion by allowing paired landings during poor visibility at the notoriously fog-bound San Francisco air-

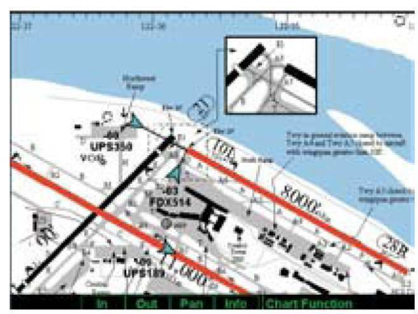
Aviation Internet

When airplanes exchange streams of data, new cockpit displays are possible. In the United States, only cargo airlines and Alaskan bush pilots have anything like these so far.

AIR TRAFFIC: **Even in poor weather, pilots could see nearby aircraft; but all planes would need the new datalink.**



MOVING MAP: **To avoid "controlled flight into terrain"—crashing into mountains—add a topographical database.**



RUNWAY TRAFFIC: **New displays could show all airplanes and runways, but some worry about overloading pilots with data.**

COURTESY OF UPS AVIATION TECH-

WEATHER: **Pilots could see storms without relying on air traffic controllers, and avoid hazards without long detours.**

port, where the runways are a whisker-close 250 meters apart. But the idea proved impractical in the short term, says Dave Jones, who directs United's efforts to improve efficiency at its San Francisco hub. To implement the strategy, United realized it would need Boeing and Airbus to approve new cockpit displays, pilots and controllers to accept them, and the FAA to certify equipment and applications. And even if United had installed the system, its airplanes would still have had to get in line with other airplanes lacking the technology. In the face of these obstacles, the airline shelved the plan and is exploring advanced radar-based tools and procedures instead.

United's experience illustrated a fundamental difficulty in implementing this new technology: it's an "all or nothing" proposition. Unless all airplanes around a given airport are equipped with it, the system can't be relied upon for spacing, collision avoidance or much else. "There's got to be a whole architecture of the airspace that everybody has got to agree to," says Robert Rosen of NASA's Ames Research Center in Moffett Field, CA. "None of that is in place today. It [ADS-B] is kind of like a piece of the puzzle, and it may even be a cornerstone of it. But having it in place is still far from having solved many of our problems."

The case for satellite tools is far more compelling where radar infrastructure is spotty or nonexistent—and where the safety benefits are obvious. One such place is Alaska's 260,000 square kilometer Yukon-Kuskokwim Delta region, where small-airplane deliveries and transportation are an essential way of life—and death. Much of Alaska has no radar coverage, no air traffic control towers and no paved runways (gravel airstrips are a luxury), making the area more like remote regions of Africa or China than the lower 48 states. The 1990s saw an average of one aircraft accident in Alaska every other day, including 186 fatal crashes leaving 398 people dead. During that decade, Alaska accounted for 37 percent of the nation's total aircraft accidents and 20 percent of total air-crash deaths.

In 1998 this carnage prompted Congress to appropriate $11 million to install new equipment in 155 small airplanes in Alaska. UPS Aviation Technologies provided the avionics, and now the GPS-based system is being used by Anchorage-based air traffic controllers to guide small aircraft in the remote, marshy delta. And while radar-devoid countries like Australia and even Mongolia are starting to deploy satellite air-traffic tools, the Alaskan region is the first place in the United States—and the only one in the foreseeable future—to move to 100 percent satellite-based air traffic control. (In the UPS experiment in Louisville, radar would still guide aircraft to and from airports. The satellite tools would only aid approach and departure spacing.)

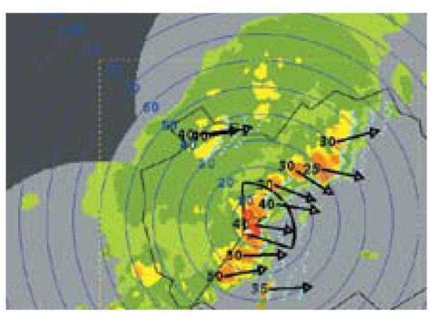
Whether the technology can make similar inroads elsewhere is less clear. One concern has been whether GPS satellite signals are robust and reliable enough to serve as a foundation for air traffic control. But a 1999 report by the Johns Hopkins Applied Physics Laboratory helped allay fears that satellite signals—weak compared to ground-based radar—are at risk of disruptions from solar radiation, atmospheric disturbances or terrorist hackers. "Technologies are emerging that can greatly reduce vulnerability to GPS signal jamming," according to the study. And to the extent that satellite signals are warped by the atmosphere or other interference, they can be verified and tweaked for extra accuracy with ground-based augmentation systems like those being installed by Raytheon.

Another fundamental question is whether new displays in the cockpit

Eyeing the Storm

While weather is a factor in 70 percent of air traffic control-related delays and 30 percent of accidents, weather displays used by air traffic controllers aren't much better than those on the evening news: Doppler radar images of precipitation. "It's just reflectivity. They have no depiction beyond what the radar can see. You could have a big storm within an hour of the airport, and the controllers don't see it," says Raymond LaFrey of MIT's Lincoln Laboratory.

Now, after more than a decade of development and prototype testing, a production model of a new weather display and prediction system is due for tests this April and May in Houston, where it will monitor skies over both the city's airports. The technology combines weather information gathered from several kinds of radar stations, as well as from lightning detectors and aircraft-mounted sensors. The data are processed in real time at air traffic control centers, with algorithms churning out near-term predictions. "It provides a very detailed current look at what is going on, and an automatic 20-minute prediction of what will happen in the future," says Robert Meyer of Raytheon, which is building the Lincoln Labs-designed system.



COURTESY OF RAYTHEON

The system shows wind speed and direction at multiple points (black arrows), precipitation density (in six colors) and rolling 20-minute storm front predictions.

Vivid displays show wind speeds and direction at multiple points, precipitation density in six colors, storm cells and front movements. The system—known as the "Integrated Terminal Weather System," or ITWS—can predict wind and weather conditions occurring as far as 300 kilometers from the airport, or right over the runways. LaFrey says it is the most detailed weather prediction system ever devised. "There hasn't been an effort to integrate that many sensors."

Beyond the safety benefits, the system could ease congestion. Knowing where and when the weather will arrive—or if it will skirt an airport—can help controllers make better decisions about how to reroute planes and when to close airports. Prototypes have been tested in Orlando, FL, Memphis, TN, Dallas and New York by the FAA and airport operators. The FAA is planning nationwide installation of 33 new systems, pending the Houston performance tests.

might distract pilots, and whether new navigation responsibilities will overload them. "Human error is involved in at least 80 percent of all accidents and incidents in aviation," says Kim Cardosi, manager of "human factors" programs at the U.S. Department of Transportation's Volpe Center in Cambridge, MA. "The work environment is so complex, it can set them up to make mistakes, and that's what we have to guard against in these systems and displays. We have to make sure [pilots] aren't overwhelmed by information, and that when they do make a mistake it can be corrected before it has serious consequences."

The infusion of data and displays brings with it new sources of confusion. Kuchar cites "a number of accidents in which there has been a mismatch between what the computer was thinking and what the human was thinking," such as the 1995 crash of an American Airlines Boeing 757 on approach to Cali, Colombia. The airplane slammed into a mountain, killing 160 people, when the autopilot was instructed to fly toward a radar beacon the pilot thought was near Cali, but which was actually near Bogotá. In this case, radar beacon technology and the autopilot system helped lead passengers to their deaths after a seemingly trivial pilot error. "If the United States switches to widespread use of [satellite-based technology], there will be other areas in the world that haven't, requiring pilots to use different procedures in different places. This can lead to additional errors and problems," Kuchar warns.

Despite these questions, prototypes are advancing. A key day for UPS's effort came last October, when FAA administrator Jane Garvey flew into Louisville for a joint FAA/UPS evaluation of the technology. Garvey stepped inside a UPS Boeing 727 whose fuselage had none of the usual furnishings—just several pods of computer equipment in the front, and 16 leather-upholstered first-class seats bolted to the floor in the rear. Taking a seat in the front row, she glanced at a computer monitor displaying a graphical depiction of the Louisville airport. The runways were dotted with slow-moving brown triangles. These represented airplanes equipped with the datalink system, exchanging position data with each other. "This is cool," Garvey said.

"Wait until you see the in-flight movie," quipped George Cooley, an engineer at UPS Aviation Technologies. The "movie" began as the 727 rolled slowly along the airport's taxiways. Other taxiing airplanes were plainly visible on the screen. Suddenly, a blue triangle appeared on the screen, its tip elongated with a needle-nose indicating high speed. A moment later, the blue blip turned brown. Jim McDaniel, head of the FAA's technology assessment programs, announced that an airplane had just taken off. But in fact, blue denoted an airborne airplane, brown an airplane on the tarmac. A moment later, he corrected himself. "I thought it was taking off at that moment, but it was landing," he said.

The demonstration was only intended to show how the technology could augment runway awareness, and its basic benefits were apparent. Even in foggy weather, the cockpit display would have given a clear view of runway traffic and immediately made apparent any wrong turn. The system worked perfectly. On the other hand, its interpreter—in this case, an experienced FAA official—had briefly been confused by the display. The mistake was an apt demonstration of why approval of new technologies for air traffic control takes time: to ensure all sources of confusion have been ferreted out.

As UPS pushes its case, a consensus is emerging that growing demand will force changes in the nation's air traffic control system. In the short run, some relief may come from airport expansion and new construction; some airports are also considering higher peak-period landing fees to discourage the rush-hour crush. Late last year, the FAA announced a lottery system for the assignment of flight times at LaGuardia—which by itself accounts for about one-quarter of the nation's delays—to reduce congestion. New procedures and uses of radar tools are increasing capacity at airports like Dallas-Fort Worth. The FAA, for its part, notes that even in busy cities the system has plenty of capacity at off-peak times. "All of the technologies that we are working on address a piece of the pie, and together they will ultimately create more capacity, but it is going to be incremental, at best," says Kathryn Creedy, an FAA spokeswoman.

However, NASA's Rosen projects that the FAA's incremental approach will only keep pace with demand for the next decade or so. "Because of the demand on the system, all the technology developers are focusing on next-generation tools," Rosen says. "But we recognize that even after all these tools are in place and working together, demand is such that it would soon again exceed capacity."

"Gridlock is in the eye of the beholder," says NASA's Robert Rosen. "However, everyone agrees that it will get worse before it gets better."

The basic technologies for satellite-based air traffic control—the GPS system, datalinks, computational power and compact cockpit displays—are on hand. But there is nothing close to consensus on how—and whether—to deploy them widely. So far, the public outcry hasn't been loud enough, the airlines haven't seen the business case, and the FAA hasn't tried to force a systemwide change. "Gridlock is in the eye of the beholder," Rosen says. "However, everyone agrees that it will get worse before it gets better."

Last October, UPS got good news: the company received the first FAA certification for its new cockpit device. It was only a small step and only for a very limited purpose, to help pilots gain "enhanced see and avoid" capability in the skies over Louisville. But the approval did signal that the system is making its way onto the regulatory radar screen. "There are still a lot of challenges with this—a lot to be resolved," McDaniel says. "The pilots and air traffic controllers are excited; there's a lot of potential, but they are not the least bit bashful about what it needs—for instance, [reducing] the clutter on the screen."

If those problems can be ironed out, however, the UPS initiative at Louisville just may be the first step in helping reduce clutter in the skies. ◊

BY DAVID H. FREEDMAN

Flying Made Easy

IT AIN'T THE JETSONS. BUT NASA AND FRIENDS HAVE A PLAN FOR REDUCING AIRLINE AND HIGHWAY CONGESTION: FLY YOURSELF TO A COMMUNITY "SMARTPORT" IN AN IDIOT-PROOF MINI-SUPERPLANE.

I recently traveled from outside Boston to Groton, CT—a popular trip in these parts, thanks to a nearby casino—and then on to Cape Cod, before returning home. It's about a five-hour drive, if the traffic isn't too bad. I did it in a little over two hours, by flying. Not a commercial flight: just driving to Boston's Logan Airport, checking in and boarding takes two hours. I flew myself in a rented Cessna, for a total cost of $160—a cost I could have split up to four ways if I had gone with friends. Besides being quick and relatively cheap, the trip afforded stunning panoramas of explosively colored fall foliage and ragged shoreline inaccessible from the earthbound perspective of a car or through the plastic peephole of a 747.

That's the good news about flying a small plane. Here's the bad news: before the flight, I had to pore over charts and airport directories, compile lists of radio navigation aids, digest a long weather briefing, and calculate wind correction angles and fuel consumption figures. Throughout the flight I had to engage in streams of aviationspeak ("Cessna one-eight-hotel, report left base following Warrior, confirm you have traffic in sight, winds three-three-zero at nine") and actively monitor eight gauges.

PHOTOGRAPH COURTESY OF CIRRUS DESIGN

User-friendly: Cirrus's SR20 heralds an era of heavily computerized, easy-to-fly, safe aircraft that could make us a nation of flyers.

To land, I had to adjust carburetor heat, lower wing flaps, and turn the plane askew to compensate for crosswind, among other tasks, all while remembering that an omission or error could have been fatal—the sort of error that plays a role in a third of the 700-odd non-commercial aircraft deaths that occur each year. And this was in clear skies; flying in clouds brings a quantum jump in complexity.

No wonder a mere 26,000 people or so earn pilot's licenses each year, compared to some four million who get driver's licenses. And this despite the fact that our increasingly mobile population is choking on clogged roadways and an often near-gridlocked commercial airline system—while the runways at some 4,500 small public airports mostly sit empty.

But this picture could change dramatically over the next decade if ambitious programs jointly undertaken by NASA, the Federal Aviation Administration, small-aircraft manufacturers and university researchers remain on track. The general goal of these programs: making small aircraft as easy and safe to operate as cars—maybe even easier and safer—and almost as inexpensive.

At the heart of this nascent transformation are new systems, components and designs aimed not so much at commercial airliners and corporate jets, the traditional beneficiaries of advances in aviation technology, but at some of the smallest and least costly aircraft made. Able to do everything from avoiding other aircraft to correcting for wind and assisting landing, these technologies are so heavily computerized and user-friendly that the cockpit in a leading-edge small plane is looking less like the console of a steam locomotive and more like the interior of a luxury sports sedan modified for Web surfing. What's more, these systems are being built to take advantage of new weather radars, position sensors and air-traffic monitors that can convert the humblest of community airports into high-tech "smartports" able to automatically accommodate a stream of planes. The eventual result: even relatively unskilled pilots will be able to home in on runways, even in bad weather, with negligible chance of things going wrong. Sums up Keith McCrea, air service and policy coordinator for the Virginia Department of Aviation, "These improvements will make flying so intuitive that any dummy will be able to do it, and without a lot of training."

Flying for Dummies

It's been a long time coming. Drive over to the nearest small airport—it's almost certainly less than a half hour away—and peek in a window of any of the four- or six-seat aircraft parked on the ramp.

"These improvements will make flying so intuitive that any **dummy** will be able to do it, and without a lot of training."

Chances are you'll be looking at a control panel dominated by a dozen or so needle-and-numbered-dial gauges, making it mostly indistinguishable from a panel that came off an aircraft assembly line in the 1950s. In flight, an experienced pilot can glance at the dancing needles in these gauges and immediately infer the plane's altitude, heading, speed, rate of turn, rate of climb and "attitude"—its angle with respect to all three axes—as well as the aircraft's rough location in relation to navigational radio stations. To a novice, however, translating the gauge readings into an understanding of the flight situation is an opportunity for serious math anxiety. "How many people enjoy doing math calculations in their heads?" asks Dean Vogel, vice president of research and development for Cirrus Design, an aircraft maker in Duluth, MN. "How many like doing them in their heads when they know that if they get the wrong answer they're going to kill their wife and kids?"

Vogel poses this gruesome question because he thinks he has the answer—at least a big part of it. In 1999, Cirrus started turning out a four-seat plane called the SR20. For a pilot used to the traditional small-aircraft panel, the SR20's console is jolting in its simplicity. Gone is the dizzying array of gauges and needles. In their place: a 26-centimeter video display fed by Global Positioning System (GPS) data that provides a literal picture of the terrain beneath the aircraft, with airport, flight route and weather information superimposed on it. "You let a computer gather the information you need and integrate it," says Vogel, "and then it presents the information to the pilot in a form that the brain understands intuitively."

And that's not the half of it. The SR20 display is the precursor of a more comprehensive set of pictorial tools being advanced under a multimillion-dollar program called Highway in the Sky that is funded chiefly by NASA, in concert with the aviation industry. A display developed under this program will be fed by GPS satellites and an onboard geographic database containing information on everything from terrain to dangerously tall antennas and airport traffic patterns. After a pilot push-buttons her way through a series of intuitive menus to program in the destination airport, the system will compare the aircraft's position to the intended flight path throughout the journey, calculating the direction in which the plane must fly to stay on course. But here's the impressive part: enlisting a graphics processor, the system will display the correct flight path as a series of hoops, lines or brackets superimposed on a 3-D-like simulated view of the airspace and terrain in front of the plane.

Flying with a Highway in the Sky display thus becomes largely a matter of lining up the crosshairs in the screen's center with the hoops or lines—a task the average 12-year-old could accomplish with one hand while working a Game Boy with the other. "I could take someone with no training and in five minutes have him flying a plane all the way through a landing," says John Hansman, an MIT aeronautics researcher involved in developing pilot control interfaces. That isn't much of an exaggeration. Technicians at NASA's Langley, VA, facilities brag that one day they grabbed a secretary who'd never sat in a small plane and got her to fly a "Highway"-equipped aircraft around a traffic pattern. And, since I happen to be the proud owner of my very own 12-year-old, I challenged Hansman to demonstrate with my son, Alex *(see "The Five-Minute Pilot," p. 62)*.

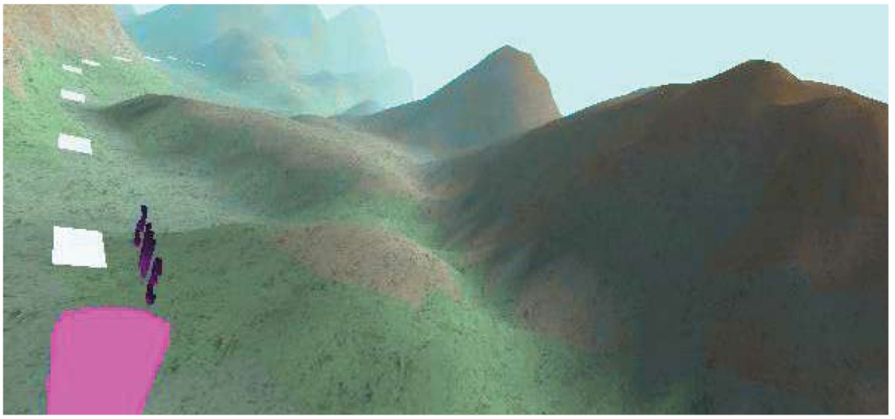
Some of the first production copies of these displays are likely to come out of AvroTec, of Portland, OR. AvroTec's new panel is going through a painstaking FAA certification process. However, it is expected to be standard equipment later this year on four-seat planes made by Lancair, of nearby Bend, OR, while also available in a "retrofit" version for older aircraft. At an expected cost of $35,000, the system is pricey, but not prohibitively so, since conventional panels run about the same. AvroTec president Mary Nolan points out that the system will lower the bar even on some of the most challenging flight situations. "A computer is perfect at calculating minute changes to a course and projecting those changes out into a flight path," she says. "That frees the pilot to do the kinds of things that the human brain is suited to, which is assimilating information and executing judgment."

Nolan offers as an example a pilot taking off from inside a cloud-shrouded canyon—an extremely hazardous scenario often encountered in the Rocky Mountains. Once off the ground and in the clouds, the pilot would normally have to estimate his location with respect to the canyon walls on a printed chart while

CIRRUS DESIGN

Lexus of the air? The SR20 console looks as if it belongs in a luxury car. The GPS-enabled uppermost screen replaces a dizzying array of gauges to show position. But where's the CD player?

watching gauge needles to make sure he stayed on course. With the new technology, the pilot would simply follow the hoops or dashed lines on the display. Because the system synthesizes its image from GPS data and onboard terrain databases—not the view from the cockpit—it works just as well in poor visibility. What's more, it would be programmed to account for the aircraft's performance capabilities—along with air density, temperature and wind data—allowing it to calculate the safest way out of the canyon. The pilot could check the projected path before takeoff, and if it passed too close to the canyon walls, he could scrub the flight and wait for better conditions.


COURTESY OF FREE FLIGHT

Follow the dotted line: The Highway in the Sky program seeks to make flying as easy as driving, in part through intuitive, 3-D-like displays that make navigation almost like tooling down the road.

The National Aviation Road Map

Highway in the Sky emerged from the Advanced General Aviation Transports Experiment, a consortium of 70 organizations that includes aviation industry manufacturers, universities and the FAA. Since its 1994 inception, the effort has been spearheaded by NASA, under director Dan Goldin's stated aim to establish a "national general aviation road map to enable doorstep-to-destination travel at four times highway speeds to virtually all of the nation's suburban, rural and remote communities." Though the original consortium effort is fading into the background, it has passed the mission on to several spinoffs, of which "Highway" is one. Another is the Small Aircraft Transportation System, a five-year, $69 million program that kicked off last year. Technically, the program is an umbrella effort that embraces Highway in the Sky and other small-aircraft technology efforts. In practice, it is focused on the other side of the equation: the airport and air traffic control infrastructure necessary to support high-tech small aircraft. After all, a fancy display system will be no better than the data it crunches; providing that data is the Small Aircraft Transportation System's mission.

Currently, flying through low-visibility conditions requires maintaining radio contact with ground-based air traffic control stations. These outposts track aircraft via radar, enabling controllers to issue verbal instructions that keep pilots on course—and out of each other's way. When approaching an airport through clouds, the pilot of a small aircraft tries to stay in the ordered pattern and zero in on the runway by repeatedly centering a needle tuned to a series of radio beacons. Every year, confused pilots fatally lose control of their aircraft. In theory, it would be far easier to track your approach on a GPS-driven display, available for $400 in handheld versions specially designed for pilots. But the standard GPS signal can be off by tens of meters—an error range that can all too easily place an approaching aircraft in a position to crash.

Part of the Small Aircraft Transportation System mission is to change all that, by providing displays with "differential" GPS signals corrected to an accuracy of as little as one meter. There are several schemes for achieving this goal, but the most significant for small aircraft is the Wide Area Augmentation System. The idea is to equip special ground stations with GPS receivers. By monitoring location information derived from the standard GPS signal and comparing that to the precisely known position of the station, it's possible to calculate the moment-to-moment error in the transmission caused by interference. The ground station then beams the corrected information to a satellite, which relays an updated, far-more-accurate signal to onboard GPS displays. Much of the system is already in place in the United States, though it will likely take a few years to work out reliability issues and achieve FAA certification for small-aircraft landing approaches.

When it does go into practice, and especially when combined with forthcoming display technologies, the Wide Area Augmentation System promises to make it far easier to touch down at airports that currently rely on instrument landing-system aids (which require pilots to align aircraft with runways by following ground-based directional signals) for poor-visibility approaches. The real benefit for small planes, though, is that the vast majority of local airports that could never justify the $1 million-plus cost of installing an instrument landing system at one end of a single runway should be able to certify both ends of every runway for poor-visibility landings for free. (Aircraft can land from either end of a runway, depending on wind direction; so authorization of poor-visibility landing from both approaches requires two systems.)

In fact, the savings for most small airports will be substantially more than $1 million. The low angles and gentle descents of instrument landing-system approaches force airports to purchase—or at least acquire easements over—large tracts of land leading up to a runway. But the greater accuracy and coverage of Wide Area Augmentation System technology enable steeper approaches, allowing the airport to minimize, or even forego, these runway protection zones. "The most important aspect of [the Small Aircraft Transportation System] is that it extends instrument landing capabilities to virtually every runway, end to end, in the nation," says McCrea, who for the next three years will be overseeing the first statewide test of the system.

In addition to providing the ability to stay on track through poor-visibility approaches into almost any runway, the Small Aircraft Transportation System also seeks to eliminate much of the need for conventional air traffic control procedures for separating planes. In their place will be a "self-separation" or "free flight" system *(see "The Digital Sky," p. 50)*, in

which each aircraft broadcasts its GPS-determined location to every other plane within 250 kilometers; a Highway in the Sky display can then adjust a plane's flight path to keep it out of everyone else's way, eliminating the need for a manned control tower at smaller airports.

Over time, as more airports install increasingly precise and affordable weather radar, the Small Aircraft Transportation System initiative will also add technologies that provide pilots with "microweather" data about an airport, including warnings of dangerous runway turbulence created by the wingtips of larger aircraft landing ahead of them. By punching through a few menus on a cockpit display, pilots will even be able to schedule fuel and maintenance services while still aloft, signal the airport rental car agency to have a vehicle waiting, or make a reservation at a nearby hotel if an unscheduled layover is in the cards. In this way, aviation authorities hope to turn thousands of community airports into "smartports," in most cases without large expenditures.

Did Anyone Say "Skycar"?

What will it cost to fly all this technology? Less than it costs to operate a mid-range BMW, according to the Small Aircraft Transportation System goals. That's not cheap, of course, but it's about half of what it costs to fly a slower, less reliable, far more difficult-to-operate plane today. What's more, Highway in the Sky systems and other easy-to-use technologies are expected to save at least 40 percent of the roughly $5,000 cost of getting a basic license today—and a like percentage on the nearly $5,000 more needed to obtain a rating for low-visibility flying.

Indeed, the emerging panorama of aviation advances raises the tantalizing possibility that planes could fly themselves, without requiring a trained pilot on board. Hansman, for one, sees that as a literal no-brainer. "With Highway in the Sky, a human pilot just acts as a meat servo," he says. "An autopilot could do it just as easily." In fact, autopilots are fairly standard equipment on most aircraft today—it's just that pilots usually have to hand-program the course and altitude information. What's more, because today's small-aircraft autopilots lack the top-notch reliability and precision needed to faithfully execute the stream of minute, rapid attitude corrections usually made in the critical seconds before touchdown, the FAA won't certify them for landings.

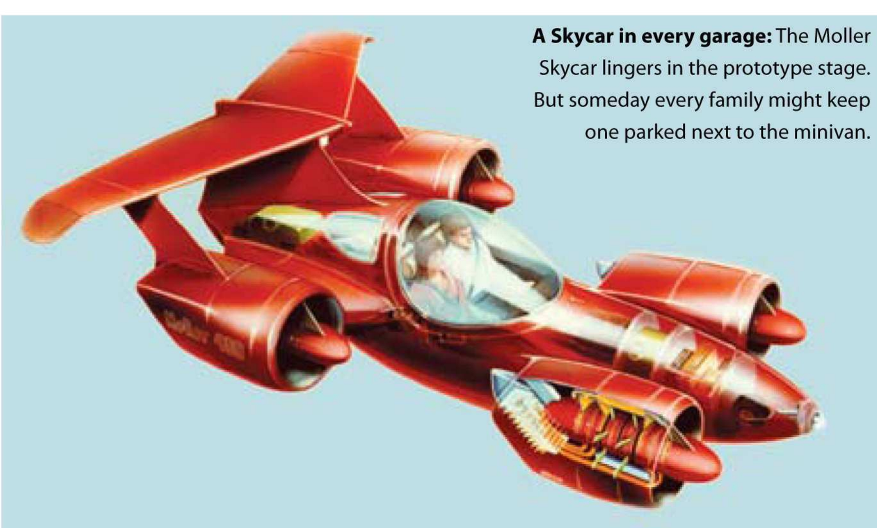
All that may be changing, however. Cirrus's Vogel contends that the eventual availability of "fly-by-wire" systems—that is, setups in which a computer oversees all aspects of a plane's controls—will provide the refinement needed to enable auto-landing. "It's going to be a while before we see planes where you just punch in your destination and sit back—maybe decades," Vogel admits. Still, he insists, that day is coming.

In the meantime, small planes should be able to at least provide backup piloting in the case of a serious mistake or other emergency, notes Dan Schwinn, president of Avidyne, a Lincoln, MA, avionics manufacturer also working on Highway in the Sky systems. "In cars you have traction control and antilock brakes, which prevent driver errors or get you out of trouble if you make one," he explains. "In airplanes you could have controls that prevent the pilot from overbanking at slow speed, or that flip you back over if you're inverted by severe turbulence."

How far will the quest for high-performance, easy-to-own-and-operate personal aircraft take us? Perhaps as far as the Skycar, an outrageously ambitious machine under development by Moller International in Davis, CA. The Skycar, which currently exists only as a prototype-in-progress, looks something like a cross between a race car and a tiny jet fighter. On takeoff, the blast of air from four large "power pods," which contain counter-rotating Wankel engines attached to turbine blades, is directed downward by louvers, theoretically allowing the Skycar to lift straight up—no runway necessary.

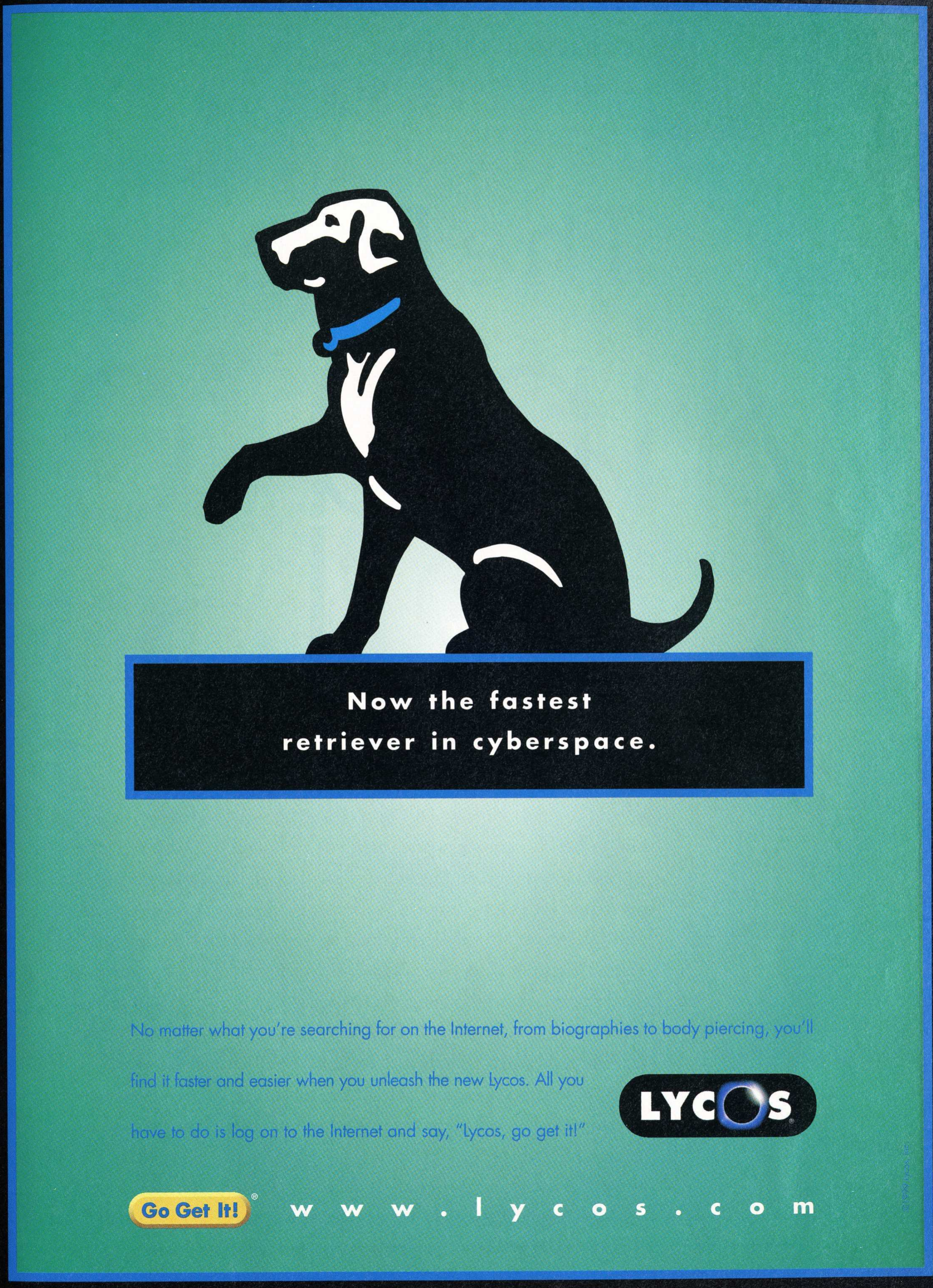
After reaching a safe height, the power-pod louvers slide back up, accelerating the vehicle straight ahead to around 500 kilometers per hour. The pilot has a pair of joysticks—one for vertical motion, the other for direction—but in essence these only serve to signal the pilot's intentions. The actual control is handled by 26 computers that assess the aircraft's position and attitude and monitor 72 components as often as 100 times a second. What's more, the Skycar is narrow enough to be driven down the road on its three wheels; it even fits in a two-car garage. Projected cost in volume production: less than $100,000. Moller has already taken deposits on early production versions, expected to go for about $1 million each, but buyers will have to stand in line behind the U.S. Army, which is gaga over the machine. "We just hope the U.S. Army is the first army in the world to get these capabilities," says Colonel Larry Harman, vice director of the Combat Service Support Battle Laboratory in Ft. Lee, VA.

Okay, so it's a little early to start marking off the backyard landing strip. But any dramatic improvement in the safety, ease of operation or cost of small planes will translate into a jump in the number of private pilots—which will help justify the investment necessary to bring on yet more improvements. In this way, we may soon find ourselves in a golden era of personal aviation, in which hopping into the family aircraft to eat at a restaurant 500 kilometers away will seem less adventurous than a 50-kilometer automobile jaunt did a century ago. ◊



A Skycar in every garage: The Moller Skycar lingers in the prototype stage. But someday every family might keep one parked next to the minivan.

COURTESY OF MOLLER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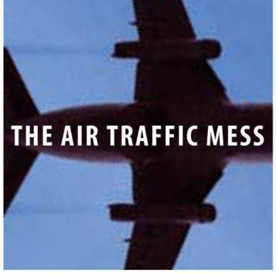


BY DAVID H. FREEDMAN

The Five-Minute Pilot

CAN NEW DIGITAL TECHNOLOGIES REALLY MAKE FLYING SO EASY EVEN A 12-YEAR-OLD WITH NO FLIGHT EXPERIENCE CAN DO IT, AS ONE AERONAUTICS EXPERT BOASTED? WRITER DAVID H. FREEDMAN JUST HAPPENS TO HAVE HIS VERY OWN 12-YEAR-OLD. SO *TECHNOLOGY REVIEW* DECIDED TO TEST MIT PROFESSOR JOHN HANSMAN'S CLAIM.

When MIT aeronautics researcher John Hansman bragged that, armed with some up-and-coming technology, he could take a 12-year-old off the street and have him or her flying a plane after only a few minutes of training, *Technology Review* couldn't resist putting him to the test. Hansman seemed game, so I presented him with a subject: my 12-year-old son, Alex. At stake in this experiment would be a question critical to the long-term vision of the NASA-backed Small Aircraft Transportation System program, which aims to ease highway congestion by making us a nation of pilots. Can an average joe with little training really get behind the controls of a small plane and, fed the right information with the right technology, pilot the aircraft from takeoff through landing?

On a frigid but sunny morning last December, Hansman met Alex and me at Hanscom Field in Bedford, MA, where Hansman's four-seat, single-engine Piper Arrow was parked. After a five-minute briefing on basic airplane control by the MIT prof in a nearby pilot's lounge, Alex climbed into the main seat, and Hansman—who has logged 6,000 hours of flying time—sat to his right behind a second set of controls. (Hansman is confident, but not foolish.)

PHOTOGRAPHS BY FURNALD/GRAY

No fear of flying: A relaxed Alex Freedman next to the Piper Arrow before his maiden flight as a pilot.

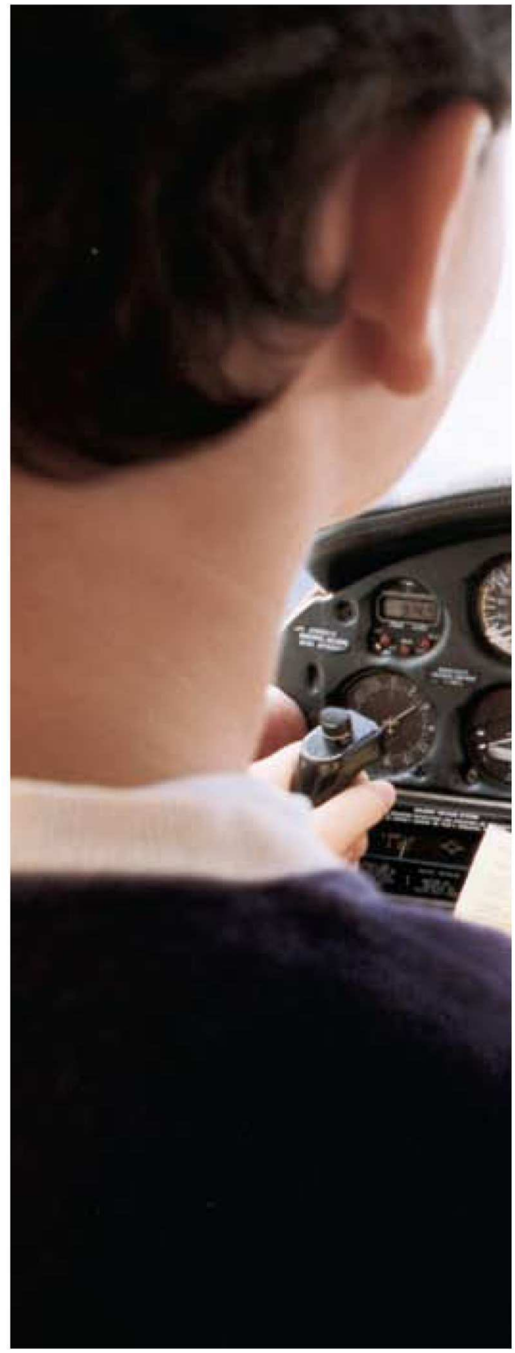
I crammed into the back next to our photographer, cradling a secret weapon: a laptop computer hooked up to a $160 Global Positioning System (GPS) receiver made by Magellan, running a prototype version of a software program called Free Flight, made by the eponymous startup company in Pasadena, CA.

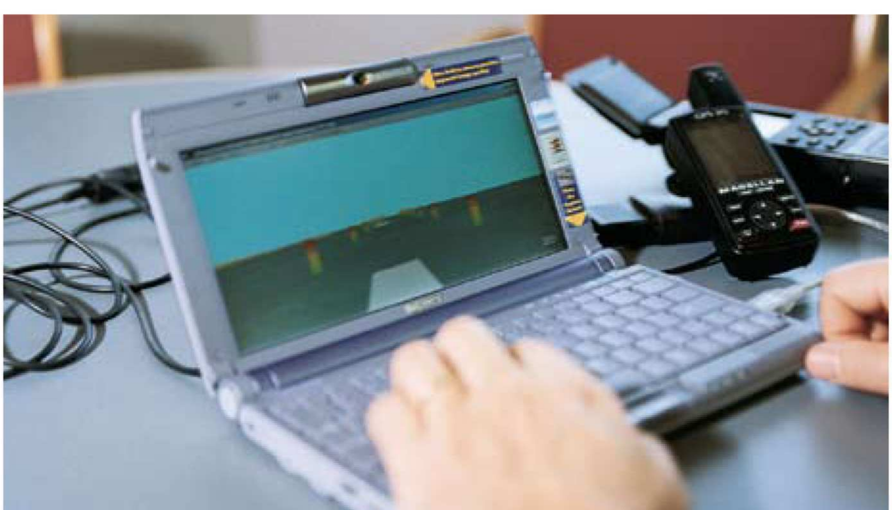
Together, the computer/GPS/Free Flight setup would function exactly like the Highway in the Sky systems slated to hit the market later this year *(see "Flying Made Easy," p. 56)*. The makers of those systems didn't have any available for our test. That's why we turned to Free Flight, which has not yet been submitted to the Federal Aviation Administration for approval. As an uncertified system, Free Flight can't legally be used as the primary means of navigation—only as an informal backup, which is how we employed it. Aside from some initial difficulties in getting the software to recognize the GPS signal, the program worked perfectly.

Our flight plan was simple enough: take off, fly about 40 kilometers west to Fitchburg Municipal Airport (away from the more heavily trafficked and controlled airspace around Boston's Logan Airport), land, take off again and return to Hanscom. Alex, normally self-assured and a tad laconic, seemed humbled by the array of gauges before him—and he nodded quickly (perhaps a little *too* quickly) as Hansman pointed out the functions of some of the gauges and reviewed the different flight controls. But when the engine roared to life, and Hansman asked if he was ready to go, Alex took a deep breath, and said in characteristic fashion: "Yup."

Moments later we were rolling across the parking ramp. Guided by common sense, his briefing on plane steering and

Flight school: Pre-flight, John Hansman briefs Alex on aircraft basics and the GPS-enabled Highway in the Sky-like navigation display. Aloft, Alex puts the briefing to the test.





Before us was a blanket of forest and farmland. A **novice** could glean no information from the aeronautical chart; there was no **intuitive** way to correlate its information with the view out the window.

Hansman's occasional barked instruction, Alex was able to taxi to the runway and take off, with just a bit of wobbling. Of course, as any pilot will tell you, taking off is the easy part. The true test of Hansman's boast would be whether Alex could get us to Fitchburg and land the plane.

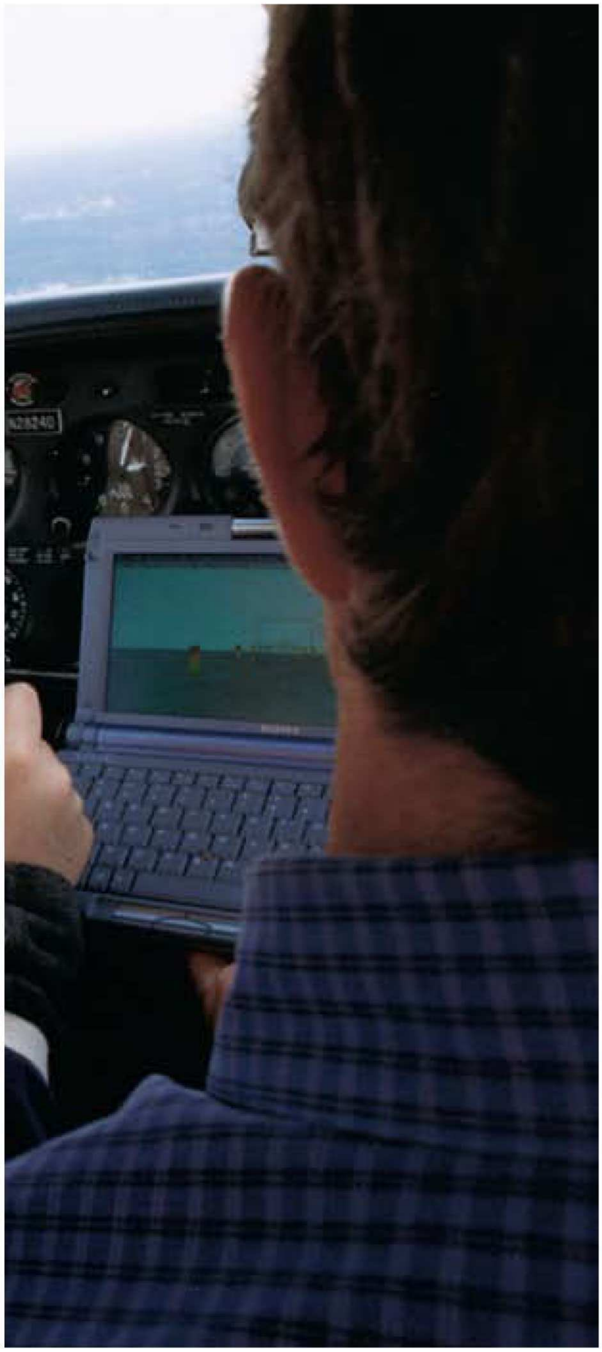
It was a clear day, and by the time we reached our cruising altitude of 750 meters, Alex seemed to have gotten the hang of the controls—and our flight felt smooth. We could easily make out downtown Boston's skyscrapers some 25 kilometers to the east, and the industrial sprawl of Lowell and Lawrence to the north.

But the westerly view before us was a blanket of forest and farmland, lifted by a small mountain here, divided by a tiny highway there—with Fitchburg nowhere to be seen. Hansman pulled out an aeronautical chart and showed Alex where we were—and where Fitchburg Airport lay. But Alex shrugged; a novice could glean no useful information from the chart, because there is no intuitive way to correlate its information with the view out the window. In short, he had no idea which way to go.

Hansman then produced a conventional $800 GPS receiver with graphic display that's popular among pilots. It depicts a simulated overhead view of the airplane with respect to ground features and radio navigation aids. But Alex only shook his head. I asked what he was thinking, and he told me the symbol-and-number-packed display was "the most confusing thing I have ever seen in my entire life." This from a kid who has never needed to read the instructions for any of the hundreds of computer and video games he has played.

By this time, the experienced Hansman could make out Fitchburg Airport in the distance, and he pointed it out to Alex. But to the untrained eye a small airport is utterly indistinguishable from the surrounding terrain, and Alex wandered off course as he searched for it. (In fact, even experienced pilots sometimes fail to rec-

With all the flair of a video **game** master homing his X-wing fighter in on the Death Star's lone vulnerable hatch, Alex immediately **banked** the airplane to bring it right on course.



Aim for the tower: Alex periodically checks the "Highway" display, keeping his course between its brackets. The distant blue tower or cone (above) signifies Fitchburg Airport.

ognize unfamiliar airports and other landmarks when navigating visually.) Here in our plane, however, we had our secret weapon. Hansman turned to me and asked if I had the Highway in the Sky-like system fired up. I did, and I handed it to him.

Hansman held the GPS-equipped laptop against the instrument panel in front of Alex. There, displayed in bright colors, sat an uncluttered image of the terrain before us. On it were superimposed two parallel lines of columns that receded into the distance, along with a blue cone planted off to the right. The lines of columns defined our current flight path, I explained to Alex, while the cone represented Fitchburg Airport. "Oh, okay," he said. "So I just need to aim at the cone, right?" With the flair of a video game master homing his X-wing fighter in on the Death Star's lone vulnerable hatch, Alex immediately banked the plane to bring the cone to the middle of the flight path. We were right on course.

In theory, Free Flight (or any FAA-certified Highway in the Sky system) could have pictorially guided Alex all the way through a landing—even in low visibility. However, because landing requires quick, minute adjustments, and because the margin for error is small and the consequences of mistakes high, Hansman wisely decided to leave Free Flight out of it. Instead, the MIT professor functioned as a sort of verbal Highway in the Sky, telling Alex which corrections to make as Fitchburg's Runway 32 loomed in front of us: "A little more to the right...nose up...add a little power..."

Alex made the approach look easy, following Hansman's instructions to level off just above the runway, cut power and then raise the nose as the slowing plane lost its lift and sunk. We touched down softly, aiming straight down the runway—a landing that wouldn't have embarrassed a professional pilot. Hansman then took the controls for about 10 seconds to execute an immediate takeoff—a timesaving "touch and go" maneuver too dangerous to leave to a rookie. Other than an occasional tweak of the power settings, this was the only time during the nearly one-hour flight when Hansman got physically involved in controlling the aircraft. (Hansman also worked the radio to make sure we had air traffic clearances and avoided other aircraft, something future Highway in the Sky systems may do automatically.)

On the way back, we once more placed Free Flight before Alex. Not only could he pick out Hanscom, he spotted the Minute Man Air Field Airport in Stow, which we would pass on the way, as well as Logan off in the distance. Again, we shut down Free Flight as we neared our goal. This approach was complicated because of the need to weave our flight path into those of other inbound aircraft. But Alex followed Hansman's instructions without trouble, and we landed with only a slight bounce. Alex then kept the controls down the runway and back to the parking ramp. After we exited the plane, he nodded toward the laptop with a big grin: "That was like playing the world's coolest video game."

Could later iterations of tools like Free Flight reliably guide inexperienced pilots from takeoff through landing, even in the presence of other aircraft? Absolutely, insists Hansman. "There wasn't anything I told Alex that couldn't have been told to him by a computer display," he says. "That's just mechanical stuff." Once pilots are freed from such mundane demands of flying, he adds, they'll be able to concentrate on weather issues and other higher-level decision making. At least until that's taken over by computer, too. ◊

An End to Alzheimer's?

BY KEN GARBER

Researchers have found a molecule they believe is a key culprit in the development of Alzheimer's disease. Now the race is on to block the molecule—and stop the disease in its tracks.

When molecular biologist Bob Vassar joined biotech giant Amgen in 1996, his mother was suffering from advanced-stage Alzheimer's disease. For years he'd taken care of her himself, since his father had died young. "Once she became incontinent I couldn't keep her at home any more," he recalls with more than a trace of guilt. In a nursing home, Vassar's mother slid rapidly downhill. In 1999, at age 78, she died—17 years after her diagnosis of Alzheimer's, which gradually but inexorably drains its victims of memory, judgment and reason.

Vassar was helpless to stop, or even slow, his mother's descent into dementia. But unlike most Alzheimer's caregivers, he was in a position to help others avoid her fate. At Amgen, in Thousand Oaks, CA, he designed and implemented an ingenious method for isolating the gene for an enzyme called beta-secretase—a key culprit in the disease. "It was a high-risk project, and there was no guarantee we could get it," says Vassar. In fact, his group individually tested 860,000 gene copies before finding beta-secretase and publishing the discovery in late 1999.

With success came hope. The U.S. Food and Drug Administration has approved three drugs for Alzheimer's disease, but these only temporarily improve brain function, without slowing or stopping progression of the disease. Other treatments are in

PHOTOGRAPHS BY ROBERT SEBREE AND WALTER SMITH

SEBREE

On the front lines: Bob Vassar (left) and Martin Citron are leading Amgen's charge against Alzheimer's.

advanced development *(see "Bulging Pipeline," p. 73)*, but none has yet shown good long-term results. The discovery of beta-secretase, on the other hand, opens the possibility of halting the disease. "It's a huge leap forward," says Lennart Mucke, director of the Gladstone Institute of Neurological Disease at the University of California, San Francisco. Possession of beta-secretase (discovered, almost simultaneously, by three other drug companies) has now set off a frenzied race to find and test a drug to block the enzyme and stop Alzheimer's in its tracks.

Untangling Alzheimer's

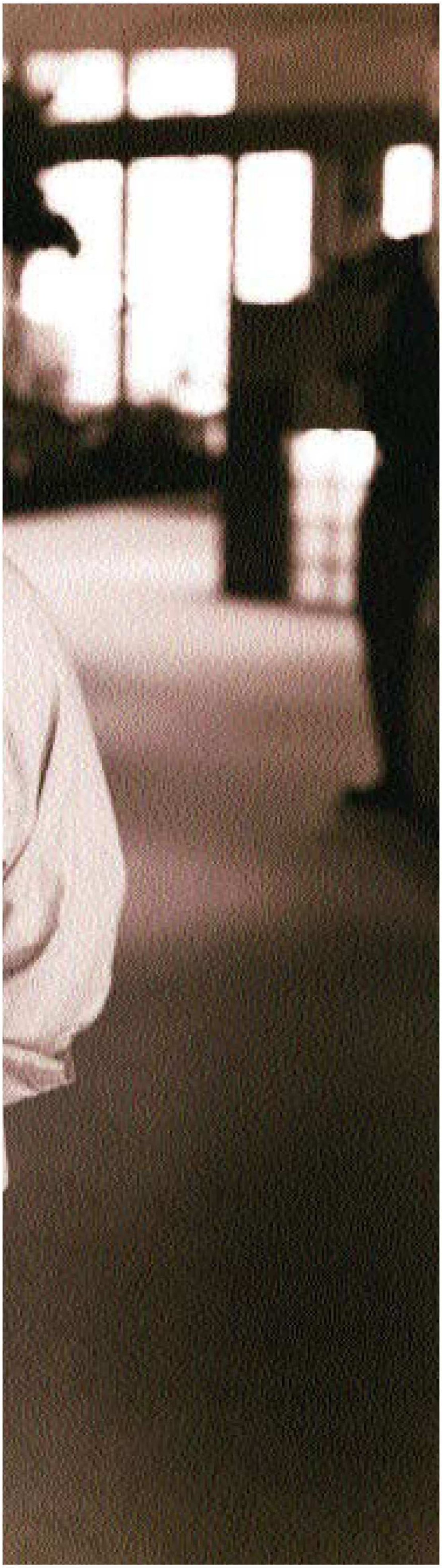
A lot is at stake. Over four million people in the United States suffer from Alzheimer's, which strikes at least 35 percent of those over 85 years old. According to gerontologist Mark Monane, a stock analyst for Needham in New York, the direct and indirect costs of the disease are more than $100 billion a year in this country alone. "There's a huge public outcry to have effective treatments available," Monane points out.

The financial stakes also are enormous. "By the year 2005 or 2010 the market could approach $8 billion," says Alzheimer's researcher Kevin Felsenstein of Bristol-Myers Squibb's pharmaceutical lab in Wallingford, CT. Any drug would likely be taken for life—a pharmaceutical company's dream. "If anything is going to define what a megablockbuster is, I think this would," says Felsenstein.

Yet, until very recently, Alzheimer's was so poorly understood that scientists despaired of finding a treatment, much less a cure. "Fifteen years ago we had no clue about how to treat this disease," said University of Pittsburgh researcher Steve DeKosky at the 2000 World Alzheimer's Congress. That confusion has persisted since 1906, when German neurologist Alois Alzheimer performed an autopsy on a woman in her 50s. In the woman's brain, Alzheimer found "tangled bundles" inside neurons, and dense deposits of a "peculiar substance" between the nerve cells. But what these "tangles" and "plaques" consisted of remained a mystery for three-quarters of a century.

Then, in the mid-1980s, scientists determined that the tangles consisted of a protein called tau, and the plaques con-


Megablockbuster: Bristol-Myers Squibb's Kevin Felsenstein says a successful Alzheimer's drug would be a pharmaceutical company's dream.



SMITH

tained a small protein fragment—or peptide—called beta-amyloid, which was a piece of a larger "amyloid precursor protein." Which feature causes Alzheimer's disease—tau or beta-amyloid (which is sometimes called BAP)—has been hotly debated ever since, leading to acrimonious battles between so-called Tauists and BAPtists. The BAPtist camp, led by Harvard neurologist Dennis Selkoe, gradually prevailed, although not all Tauists have surrendered. "I would guess that probably 80 percent or more in the field would now agree that amyloid plays a critical role," says Amgen molecular biologist Martin Citron, who worked in Selkoe's lab from 1992 to 1997. Selkoe, Citron and others believe beta-amyloid is either directly toxic to cells, or provokes inflammation that kills neurons, or both.

By the early 1990s, researchers had pieced together a model of what might be going on in Alzheimer's patients' brains. Amyloid precursor protein grows like a blade of grass out of the membrane that covers each nerve cell. Normally, researchers hypothesized, two scissorslike enzymes called alpha-secretase and gamma-secretase work in series to clip the amyloid precursor protein first near its base and then right at the base; the short peptide that results from the second cut is harmless. Sometimes, though, rather than the alpha enzyme, a beta version makes the first cut—and in a slightly different spot. When the gamma enzyme comes along and makes the second cut, the resulting fragment is beta-amyloid. In Alzheimer's, the theory goes, beta-amyloid piles up between the brain cells, forming plaques and gradually killing surrounding cells *(see "Plaque Busters," p. 74)*.

Blunting the Scissors

Although the cutting enzymes themselves proved maddeningly elusive, this model of Alzheimer's offered an obvious strategy for attacking the disease: block the enzymes and prevent the plaques. Since 1992, many drug companies have been looking for "secretase inhibitors," molecules that would block either gamma- or beta-secretase. One compound, a gamma-secretase inhibitor discovered at Bristol-Myers Squibb using mass screening techniques, entered early human trials in April 2000. "We're on the verge now of either preventing amyloid deposits from building up, inhibiting the production of amyloid, or actually being able to reverse plaque deposition," says Felsenstein, who leads Bristol-Myers Squibb's amyloid program. Other pharmaceutical firms—including DuPont, Merck, Elan and Eli Lilly—are testing gamma-secretase inhibitors as well, but haven't yet

Bulging Pipeline

So far, only Bristol-Myers Squibb is known to be testing a secretase inhibitor in humans, but several other types of Alzheimer's drug are already in clinical trials in the United States.

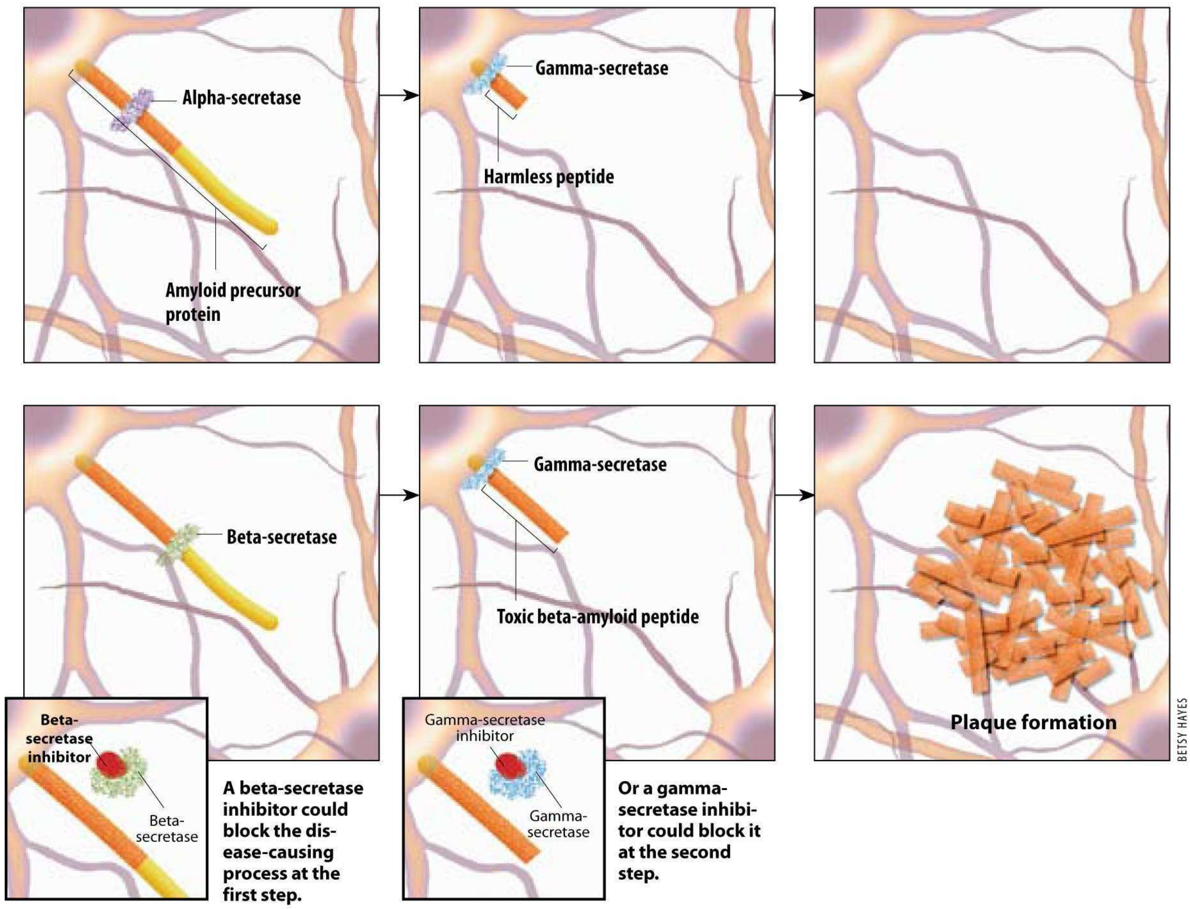
COMPANY	DRUG	POSSIBLE ACTION
Axonyx (New York, NY)	Phenserine	Maintaining nerve signals
Cortex Pharmaceuticals (Irvine, CA)	Ampalex	Enhancing nerve signals
National Institutes of Health (Bethesda, MD)		
Ebewe Pharmaceuticals (Unterach, Austria)	Cerebrolysin	Promoting nerve growth
Elan (Dublin, Ireland) American Home Products (Madison, NJ)	AN-1792 (vaccine)	Provoking immune system to remove plaques
Forest Pharmaceuticals (St. Louis, MO)	Memantine	Correcting nerve signaling malfunction
Immune Network (Vancouver, BC)	Dapsone	Blocking inflammation
Merck (Whitehouse Station, NJ)	Vioxx	Blocking inflammation
NeoTherapeutics (Irvine, CA)	Neotrofin	Promoting nerve growth
Shire Pharmaceuticals (Andover, England)	Reminyl	Maintaining nerve signals
Sigma-Tau Pharmaceuticals (Pomezia, Italy)	ALCAR	Promoting nerve growth

Plaque Busters

Secretase inhibitors could stop the Alzheimer's disease process in one of two places.

1. In a healthy brain, amyloid precursor protein is cut first by alpha-secretase, then by the gamma enzyme. The fragment, or peptide, produced by the second cut is harmless.

2. In Alzheimer's, beta-secretase makes the first cut instead. Then gamma-secretase cuts and releases the beta-amyloid peptide, which clumps between cells, forming deadly plaques.



disclosed human trials.

But the drug-discovery process has been agonizingly slow. Just randomly sprinkling compounds on cells and measuring amyloid levels requires both time and luck to get a good hit. In fact, many drug companies ignored the secretases, since without the enzymes in hand, there's no way to know how specifically a compound is targeting them—making toxic side effects largely unpredictable.

Finding beta-secretase changes everything. Now medicinal chemists can design molecules to fit precisely into the enzyme's "active site." In theory, such drugs should be exquisitely specific, avoiding the worst side effects. Citron says Amgen is very excited about that possibility. The company has figured out the three-dimensional structure of the beta enzyme and is fashioning molecules to block its activity.

Industry insiders say that Amgen has lots of competition, though companies are more open about their gamma programs. GlaxoSmithKline of London, another company to have isolated the beta-secretase gene, is one player officially working to inhibit it. And Dublin, Ireland-based Elan and its partner in Peapack, NJ, Pharmacia, have also launched a major push. "Both of us view beta-secretase as a terrific target," says Dale Schenk, vice president of discovery research for Elan. "I don't think it's going to be terribly long before the field has clinical candidates."

Schenk's optimism is based, in part, on an obvious precedent: AIDS. That's because beta-secretase is a protease, or protein-cutting enzyme, in the same class as the HIV protease, which proved to be a great drug target. Once the HIV-protease structure was discovered in 1989, it took less than three years to get "protease inhibitors" into the clinic. These drugs have changed AIDS from a death sentence into a usually manageable condition. "Pharmaceutical companies like sure things," says University of South Florida Alzheimer's researcher Huntington Potter. Blocking enzymes "is something they can do easily and be sure that they have something fairly successful at the end."

Progress Inhibited?

But there is a big question: what if the amyloid theory is wrong? If it is, secretase inhibitors would be useless. "The field has been 'sold,' or has willingly bought into, the hypothesis that amyloid deposits, or possibly the precursors to the amyloid deposits, actually cause the disease," says Potter. "It's probably true." But other factors—tangle formation, for example, or disruption of neurons' stores of the calcium ions critical to nerve firing—could prove to be the real cause of Alzheimer's. In that case, "getting rid of [amyloid] might make a cleaner brain, but it might not make a more functioning brain," says Potter. "We won't know until [drugs] are tried."

Even if the amyloid hypothesis proves correct, side effects could ultimately

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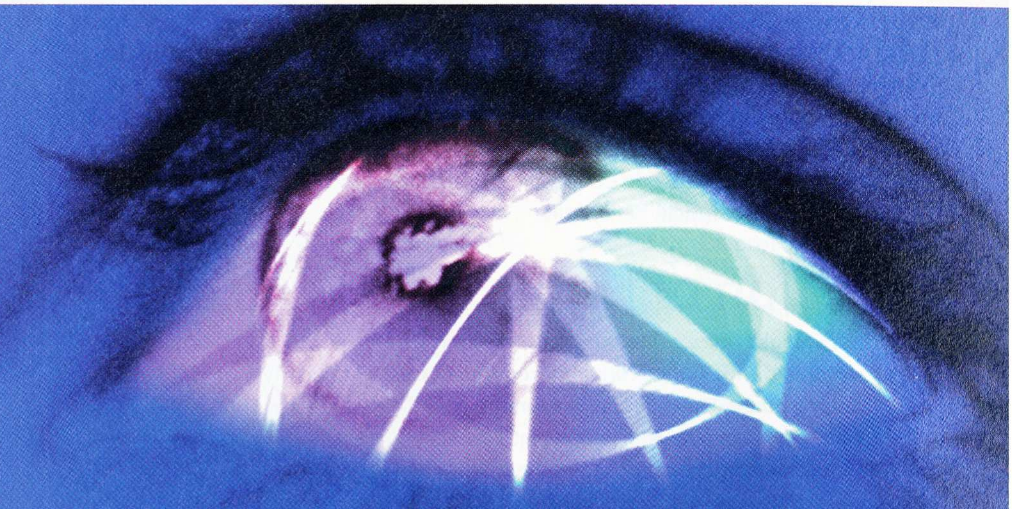

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function. "It's going to take an army of lawyers to figure out who owns it," says Felsenstein. Meanwhile, the pressure to get to market ahead of competitors is intense. As one drug-company researcher confided, "My CEO says it's costing us $150,000 a day not to have an Alzheimer's drug on the market."

Stocking the Armamentarium

Though each company is desperate to be first, many will likely emerge with successful (and lucrative) drugs. "The field is wide open," says Needham's Monane. "There's room for multiple winners in the race." And, indeed, most researchers in the field agree that no single drug is likely to work for every Alzheimer's patient.

Instead, it will probably take a "cocktail" approach, analogous to today's AIDS therapy. So, although secretase inhibitors and a vaccine effort at Elan *(see "Injection of Hope," p. 76)* hold the most promise now, other classes of drugs could also be useful. "We will probably find out that many different things are contributing to this disease," says the University of California, San Francisco's Mucke. "And it is worthwhile to develop treatments to hit each one of those, and then see what combination will be most effective."

How soon will this happen? "I predict that we're going to have an armamentarium of drugs in the next five years—10 years maximum—some or many of which will be effective," says Potter. "It's going to be longer before we can say that we've cured the disease."

Meanwhile, Amgen's Bob Vassar continues working on beta-secretase. His family history of Alzheimer's weighs on him constantly. He knows his mother may have had an inherited form of the disease—one that could have been passed on to him. "I'm worried about myself, and wondering what's going to happen to me," he says. Vassar, who's 44, thought of being tested for the defective genes but decided against it, figuring it would only add to his stress. Instead, he says, "I'm hoping in the back of my mind that either Amgen or another company comes up with an effective inhibitor." He knows it won't happen overnight. "But hopefully, by the time I need it, it will be there." ◊

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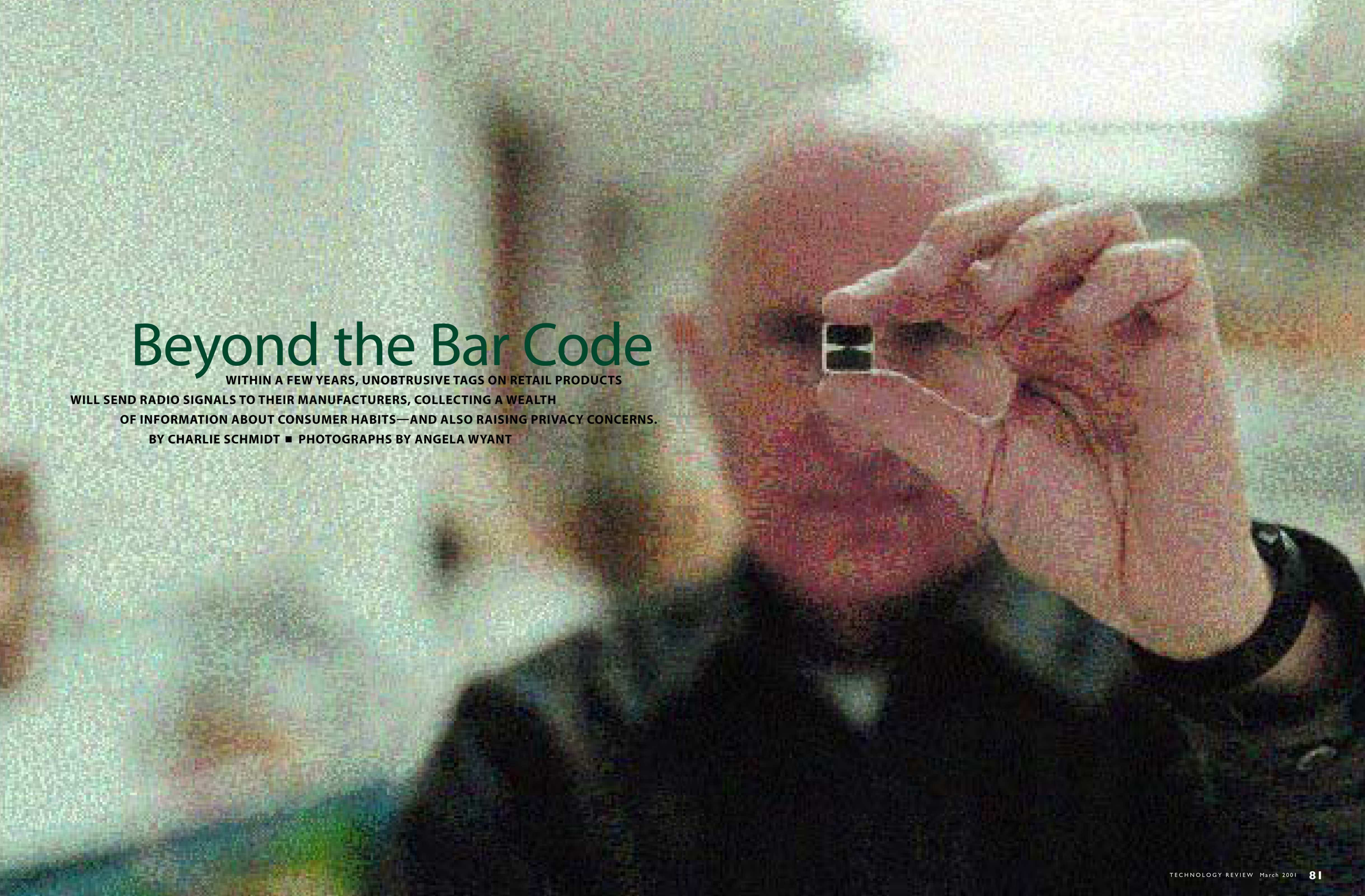


Beyond the Bar Code

WITHIN A FEW YEARS, UNOBTRUSIVE TAGS ON RETAIL PRODUCTS WILL SEND RADIO SIGNALS TO THEIR MANUFACTURERS, COLLECTING A WEALTH OF INFORMATION ABOUT CONSUMER HABITS—AND ALSO RAISING PRIVACY CONCERNS.

BY CHARLIE SCHMIDT ■ PHOTOGRAPHS BY ANGELA WYANT

It's 2010, and an ordinary day on an assembly line. A bottle of root beer gets stamped with an innocuous little tag that immediately begins sending messages into cyberspace. The tag radios the soda company's Web site to report the bottle's whereabouts, allowing computers to track the bottle as it moves from the factory, through warehouses and distribution centers, and into a refrigerator at a corner drugstore. When the bottle is sold, the manufacturer is alerted and makes a new one to take its place. Finally, facing reincarnation at a recycling plant, the bottle radios its "last words" to a robotic separator that lifts it from a pile of plastic and newspaper and tosses it into a container of broken glass.

Manufacturers hoping to recoup some of the billions lost every year to theft, counterfeit, and depleted stocks have been closely watching a technology that promises to track the locations of individual products, from perfume bottles to car parts, in real time. At the heart of this scenario is a little device called a "radio frequency identification tag"—a silicon chip that boots up and transmits a signal when exposed to the energy field of a nearby reader. The ultimate goal is to put a radio tag on virtually every manufactured item, each tracked by a network of millions of readers in factories, trucks, warehouses and homes, transforming huge supply chains into intelligent, self-managing entities. Dick Cantwell, vice president of global business management at Gillette says that the devices for reading the tags are "going to be a ubiquitous part of construction, whether you're building stores or homes….We see this as a tremendous opportunity and we intend to make full use of the technology as it becomes available."

The radio tag has been around for more than half a century, largely relegated to specialized industries. Some of its first uses were for tracking livestock and government freight-train cargo; today highway tolls throughout the United States and abroad are outfitted with readers that pick up signals from a tag in your car as you drive by. Insiders in this field believe the technology won't blanket the consumer market, though, until someone produces a radio tag costing in the neighborhood of a penny—an assumption that has sent engineers back to the drawing board.

When the penny barrier is finally broken, manufacturers hope to use these tags as a next-generation bar code linking manufactured items to online databases containing product-specific information. Steve Halliday, vice president of technology at AIM, a trade association for manufacturers of tagging technology, says, "If I talk to companies and ask them if they want to replace the bar code with these tags, the answer can't be anything but yes. It's like giving them the opportunity to rule the world."

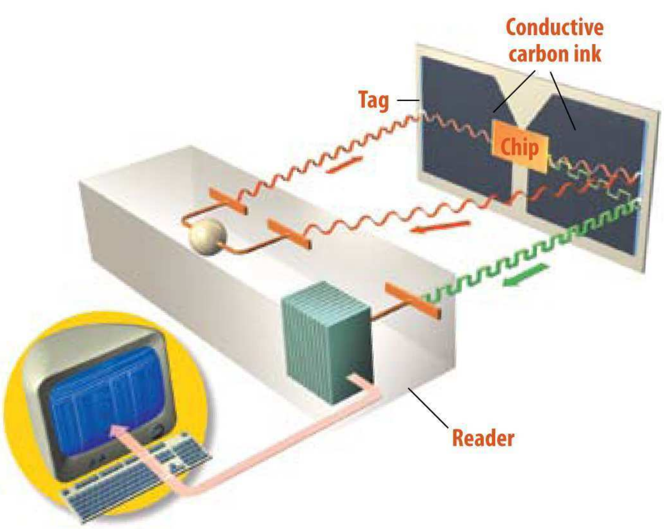
PENNIES OR LESS

Designed to speed up checkout counters and eliminate the drudgery of physical price marking, the bar code has come a long way since 1974—when it was introduced into retail sales on a pack of chewing gum in an Ohio supermarket. Far exceeding initial expectations, five billion codes are scanned every day in 140 countries. But even as retailers tip their hat to the bar code's success, few deny that a more sophisticated kind of tagging would be a great improvement. Bar codes identify only classes of products, not individual items, whereas a digital numbering scheme built into a tag has the capacity to identify *every single manufactured* item that is currently made and sold. Bar codes also have to be deliberately scanned at specific orientations; tags need only be within a reader's range. "Once the infrastructure is in place, managing inventory in warehouses and retail stores could become highly automated," says Alan Haberman, co-founder and governor-at-large of the Uniform Code Council, the organization that administers the bar code.

While attractive in concept, saturating the global supply chain with radio tags and readers poses huge challenges—chief among them the cost of the tag, typically more than a dollar. That's fine for a choice Hereford steer but much too expensive for consumer items. The high cost results from the silicon chip and from the antenna, a pricey metal coil that serves two functions. First, it uses a magnetic field emitted by the reader to power the chip. Then, when the chip is powered, the antenna transmits data from the chip back to the reader. Most manufacturers of radio tags, including Texas Instruments and Everett, WA-based Intermec, have developed tags based on this model, which is known as "inductive coupling."

It is the cost of the inductively coupled tags, hovering around a dollar, that lit a fire under Noel Eberhardt, vice president for advanced technology at Motorola. "The words that burned in my ears were 'this is interesting technology, but it's too expensive,'" Eberhardt says. "So I set out to build the lowest-cost silicon chip possible. And my first objective was to get rid of that coil."

In late 1995, Eberhardt started collaborating with Neil Gershenfeld, director of the MIT Media Lab's Physics and Media Group, on a cost-effective design. Eberhardt experimented with "capacitive coupling," an alternative method in which the tag is powered not by magnetic forces but by electrostatic charges emitted by the reader, charges similar to those that cause your clothes to stick together when you pull them out of the dryer. Using this mechanism, he found that coil antennas could be replaced with conductive carbon ink printed on paper which would pick up the electrostatic charges from the reader and



Motorola's Radio Tag

In order to communicate with nearby readers, conductive carbon ink on the tag's surface intercepts a reader's electric field, generating a current (orange) between the tag and the reader to power the chip. The tag then transmits data (green) stored on the chip to the reader, which decodes it and passes it on to a computer.

SLIM FILMS

Tale of the tape: Motorola's Noel Eberhardt wants to create the lowest-cost radio tag possible.

Naming Network

The Object Naming Service, developed at MIT's Auto-ID Center, routes radio tag information from (1) warehouses, (2) store shelves, (3) microwave ovens and (4) recycling facilities back to the (5) manufacturer. That way, Acme Pizza knows when stock is low, when to send cooking instructions over the Internet to a customer's microwave oven and when to make another pizza to replace the one that's just been consumed.

SLIM FILMS

create a current across the chip. The silicon chip—itself less than three millimeters square—could be mounted atop a sheet of paper lined with the special ink.

Without the metal coil, the cost of the tag dropped to less than 50 cents. The added flexibility of the paper material also meant Eberhardt's prototype tag could function when bent, cut or crumpled, as long as a remnant of the carbon ink-based antenna remained connected to the chip. Eberhardt and Gershenfeld announced their innovation in February 1999. Within weeks of the announcement, Motorola released the first and so far the only capacitively coupled tag.

TWO STEPS FORWARD

While Eberhardt's work moved the field closer to the penny tag, one lingering issue is whether low-cost tags will have a long enough range to make them practical. The range of Motorola's tag, for example, is limited to slightly more than a centimeter. Painting the antenna over an entire box extends the range to about 60 centimeters, but this won't help much on something as small as a can of tuna fish. Higher-cost tags, like Intermec's inductive tag, can transmit signals up to five meters but at a price beyond the reach of the typical consumer market. Echoing industry sentiments, Winston Guillory, vice president of the tag's business unit at Intermec, predicts that short-term applications will probably be limited to warehouse, rather than retail, management. And as for the penny tag, Guillory admits to a certain skepticism. "You hear all this talk about it," he says. "But it's never been delivered."

Despite the skepticism, many companies are in hot pursuit of the penny tag and its glittering potential payoff. Steve Van Fleet, International Paper's program manager for e-packaging, says the technology will benefit his company's clients by eliminating the "shrinkage" due to lost, stolen or spoiled goods that consumes three to five percent of everything they make. Last year, International Paper partnered with Motorola to use their radio tag on some of the 8.6 million metric tons of corrugated crates, boxes and other packages the paper company makes annually. Explains Van Fleet, "Say I have 5,000 cases on a truck that's supposed to be going to Cincinnati, but the driver goes to St. Louis and diverts 1,000 cases to the black market. Without the tags, we have limited visibility to detect this. But if we put readers in the truck, I can inventory these cases remotely using geographic information systems software on a laptop."

In addition to reducing shrinkage, such identification technology could help companies create a more realistic picture of how their products move through the supply chain and into the world. At Gillette, for example, sales information is transferred across warehouses, distribution centers and retail stores in batches by telephone, fax or e-mail. Since the information isn't matched with demand in real time, manufacturers often get stuck making too little, then too much,

What's My Number?

Researchers at MIT's Auto-ID Center have developed a numbering scheme called the "Electronic Product Code" that will identify consumer products individually—not just by type, as today's Universal Product Code does. Stored in the memory of the tag's chip, the code uses 96 bits of information: an 8-bit header, two sets of 24 bits each identifying the manufacturer and product type, and a 40-bit serial number. Ninety-six bits can encode enough information to uniquely identify trillions upon trillions of objects. When readers lining warehouse or retail store shelves intercept a tag's radio signal, which contains the product code, they use the numbering scheme to direct networked computers to an Internet database called the "Object Naming Service." Designed and supported by the Auto-ID Center, the database system reads the portion of the code identifying the manufacturer and directs computers to the manufacturer's server address.

In order for tags to communicate with different servers regardless of the type of computer or software encountered, engineers at MIT are also developing a format called "Product Markup Language." In the future, files written in this format will contain information on things like shipping, expiration dates, recycling and advertising. Instructions for machines that change a product in some way could also be included in these files. For example, a specific frozen-food file would have cooking instructions for microwave ovens. A dynamic data file could describe physical changes that occur as a product ages or is consumed. So while the Electronic Product Code initially identifies a physical item, the Product Markup Language describes the item, and the Object Naming Service links the two, communicating product information between a manufacturer and an aisle in your local supermarket.

product in an attempt to keep up with the market. Economists call this the "bullwhip effect."

Getting the cost of the radio tag down to a penny isn't the only major technology challenge in this field. Another is linking the tags to the Web. That effort is being led by an MIT-based consortium of academic and industry partners called the Auto-ID Center. Kevin Ashton, the center's director, anticipates the arrival of the penny tag in five years and says he is now focusing, not on the tag, but on how to create a network architecture that squeezes as much profit out of it as possible. "And profit," says Sanjay Sarma, research director at the center, "will ultimately depend on a system that allows for the seamless flow of data throughout the entire supply chain."

The system will have to scale to unprecedented proportions, potentially handling *trillions of items* annually, making it one of the largest systems ever built. "It's an enormous undertaking," Ashton concedes. The Auto-ID Center, formed in 1999, with 11 corporate members including Gillette, Procter & Gamble, International Paper, Sun Microsystems and the Uniform Code Council, is simplifying the task by hooking on to an existing system: the Internet. "Initially, it was expected that tags would need quite a lot of memory," recalls Ashton. But Sarma, along with Sunny Siu and Auto-ID Center co-director David Brock, designed a cost-saving system that makes tags extremely simple and transfers all the information about a product to the Web—a description of its constituent parts, for example, or a record of its trajectory through the supply chain. The only information actually on the tag is an Auto-ID Center invention called the "Electronic Product Code," a counterpart of the bar code that assigns a searchable number to each object *(see "What's My Number?", p. 84)*.

GETTING PERSONAL

According to Cantwell, Gillette and many other companies envision using tags to download promotional material to displays mounted on store shelves, or even to shoppers' handheld computers. By simply scanning a product in front of a networked reader linked to a computer monitor, customers could one day retrieve user instructions, specifications and other product information to help them decide, for instance, which toothbrush is more flexible or which soup has less sodium.

Talk to Cantwell awhile longer, and he's likely to bring up Gillette's next goal: using readers to track consumer use of its products at home. Gillette sees the technology engaged in direct consumer marketing, which would rely on personalized information obtained from readers installed where products are actually used—in your refrigerator, say. While this scenario may be decades away, the coming era of ubiquitous computing could bring Internet access to every household appliance. "Smart" fridges could monitor tagged products, learn your food preferences and shopping schedule, and then buy all your groceries for you. And, if you let them, companies like Gillette will monitor personal use of their products. Throw one of their razors into the trash, and another one would be on its way.

That's a vision that, predictably, has marketers salivating. But are you ready for a system that surrounds you and monitors your family's day-to-day activities? Watchdog organizations like the Center for Democracy and Technology, a Washington, DC-based public interest group focused on civil liberties, worry about new challenges to privacy. "Imagine putting a frozen pizza into a microwave that downloads cooking instructions from Pizza Hut," suggests the group's staff counsel, Alan Davidson. "Is Pizza Hut going to track the server of that microwave? Will they find out where and when you bought the pizza, and are they logging this transaction? Suddenly they have a detailed record that describes your personal activities."

One of the greatest challenges facing the creators of such an infrastructure, predicts Davidson, will be finding ways to allow consumers to opt in or out of the system as it becomes more pervasive. "It's not clear how that's going to happen," he says. "But it's important if companies want to prevent a public backlash against these systems."

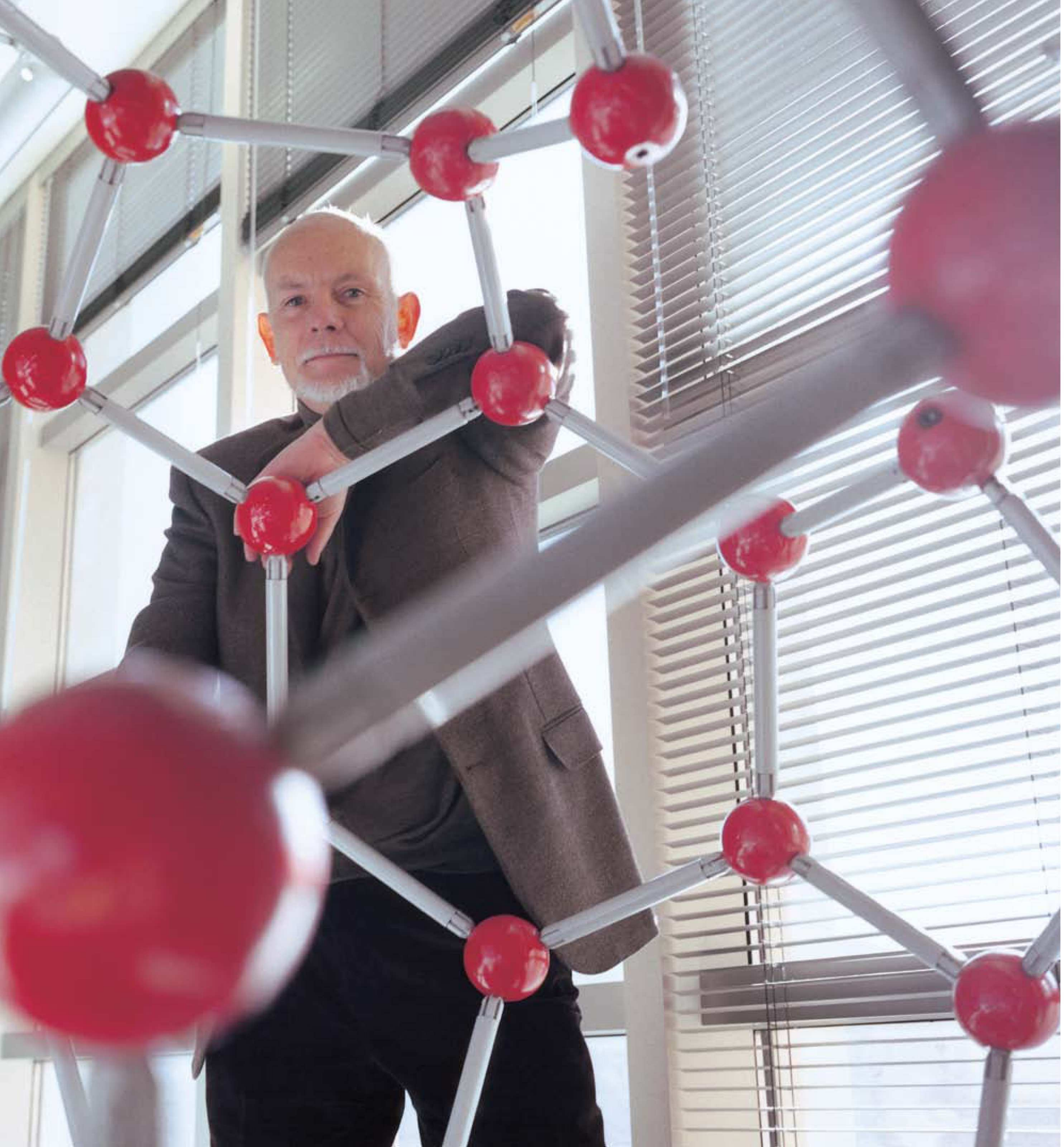
In some ways, the technology itself has certain limitations that minimize privacy concerns. The range of a tag seldom exceeds five meters, nor can the tags be read through walls or other thick barriers. What's more, Electronic Product Codes identify objects, not people. The only way for a manufacturing company to link the two is through an automatic debiting system or credit card, for which the consumer would most likely have to give consent. Sarma acknowledges that privacy and security are concerns at the Auto-ID Center, adding that industrial uses, for which these issues are minimal, are certain to emerge before consumer applications. "Security concerns will be resolved long before we get to the consumer," he says. "We are bringing a lot of technical and organizational resources to bear on this issue."

Before implementing the tagging system, the Auto-ID Center will have to seek consensus from the Uniform Code Council and its European counterpart, a process that could take two to five years. While the online infrastructure now being created could set the stage for an explosion of radio-based identification technology across the consumer marketplace, in all likelihood the change will start slowly. First in warehousing, out of the average consumer's sight. Then among some isolated and expensive retail items worthy of the investment. Until, finally, a Wal-Mart salesman shows you the latest refrigerator on the market, complete with Internet connectivity, the ability to analyze its own contents—and optional online access to your wallet. ◊

Tag Teams

Some companies manufacturing radio tags

COMPANY	LOCATION	APPLICATIONS
BiStar Technology	Oxfordshire, UK	Warehouse management, article tracking, building-access control
Intermec	Everett, WA	Supply-chain management, vehicle tracking, access control, mobile commerce
Motorola	Rolling Meadows, IL	Warehouse management, ski-lift tickets, building access, high-value consumer goods tracking
Philips Semiconductors	Eindhoven, Neth.	Airline baggage tracking, supply-chain management, tracking of retail articles
SCS	San Diego, CA	Airline baggage tracking, warehouse management, garment tracking
Texas Instruments	Dallas, TX	Tracking books in libraries, airline baggage handling, express parcel identification



Wires of Wonder

Ready for carbon fibers, stronger than steel, that could provide the cables for "space elevators" or replace all the world's electrical transmission lines? Nobelist Richard Smalley describes his "lunatic" vision of a nanotube world.

Q & A

IT WAS THE KIND of discovery that only happens in chemistry once every few decades—if you're very lucky. In 1985, Richard E. Smalley and several collaborators at Rice University made a form of carbon never seen before. The arrangement of carbon atoms in each molecule resembled a tiny geodesic dome, so the researchers called the material "buckminsterfullerene" after the architect who had popularized the shape. With its neatly structured network of atoms, the "buckyball" quickly became the poster molecule for nanotechnology. Then in the early 1990s, researchers made another startling discovery: you could also make hollow tubes out of the same carbon structure. Carbon nanotubes had many times the strength of steel, the electrical conductivity of copper, and were the diameter of a DNA molecule. They were, in short, perfect materials for building and wiring the nano world.

More than a decade after his initial discovery, Smalley's enthusiasm for the new materials shows no sign of waning. Last year he co-founded a company, Carbon

PHOTOGRAPHS BY BETH PERKINS

Nanotechnologies, to make the commercial quantities of nanotubes that will enable other labs to push the technology forward, and to develop applications. But his continuing excitement for fullerenes (as the general category of these carbon-based molecules is known) goes far beyond anticipation of future technological uses. Trained as a spectroscopist, Smalley, a chemistry professor at Rice since 1976, is fascinated by the molecules themselves. In accepting the 1996 Nobel Prize in chemistry for fullerenes research, Smalley called the discovery "one of the most spiritual experiences that any of us in the original team of [researchers] have ever experienced."

The $33 million Center for Nanoscale Science and Technology, which Smalley established in 1995 and now directs, sits at the edge of the Rice campus in Houston as a testimonial to the potential of fullerenes. The number of research groups at the nanotech center is growing so fast that Smalley's own lab has moved next door to the third floor of Rice's Space Science Center. *Technology Review* deputy editor David Rotman recently visited Smalley to ask about the future of nanotech and hear why the Nobel Prize winner thinks nanotubes are so special.

TR: How has the increased attention and funding, such as President Clinton's $495 million nanotech initiative for 2001, affected the field of nanotechnology?
SMALLEY: To have the president talk about it has emboldened scientists and technologists to start to put "nano" in their proposals. They know what the new buzzword is. But more impressive to me has been how this idea has caught hold with those out there doing science. And I don't get the feeling that it's artificial posturing. The core disciplines of chemistry and physics have warmed to this idea. Part of that has been a response to the funding. But I think there really is a general appreciation that there really is something here. The chemistry and physics have now advanced to the point that you can think of, and in some cases actually build and do experiments on, [nano] structures of sufficient complexity that something new happens.

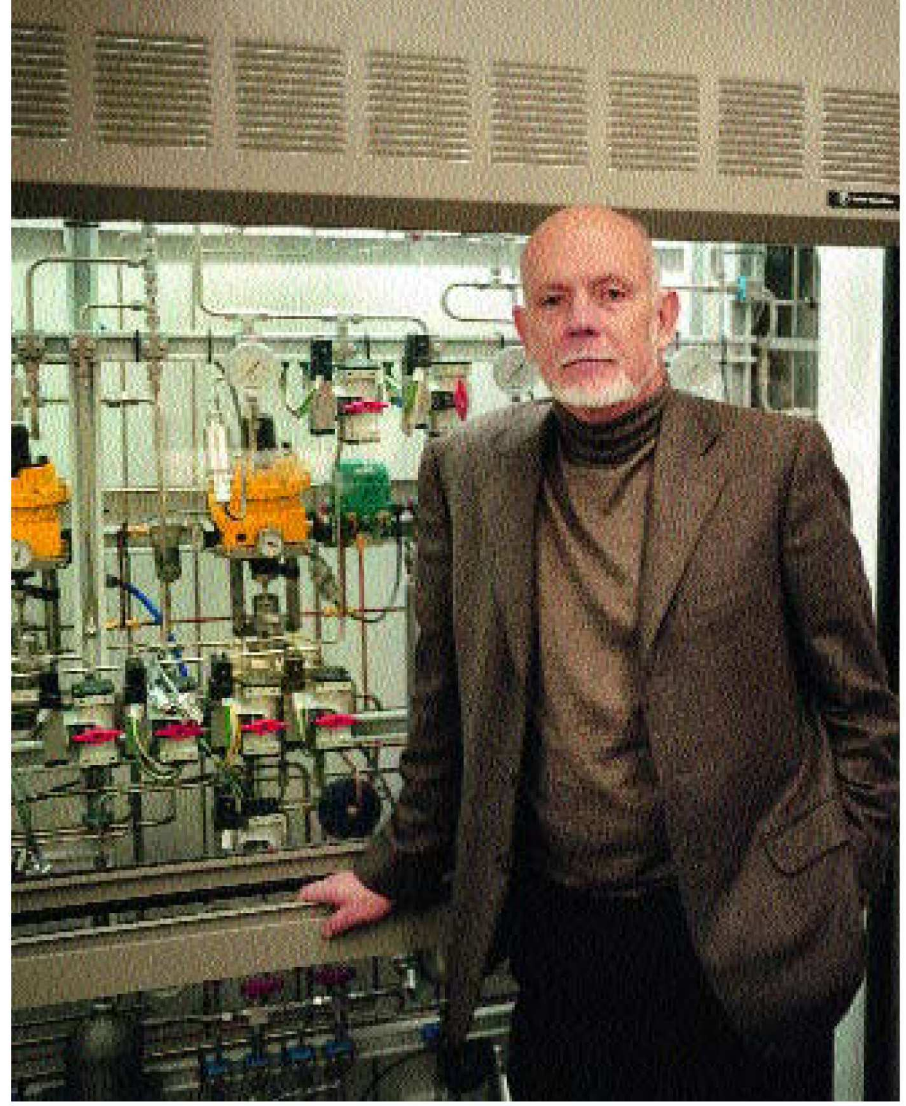
TR: Is there a danger that, like many other buzzwords, "nanotechnology" will begin to lose its real meaning?
SMALLEY: I like the word "nanotechnology." I like it because the prefix "nano" guarantees it will be fundamental science for decades; the "technology" says it is engineering, something you're involved in not just because you're interested in how nature works but because it will produce something that has a broad impact. When you put those two things together in one word, there's a tension. As our disciplines, particularly chemistry and physics, have matured, we're now dealing with things at a very fundamental level that do have a practical importance.

TR: When you look at the different work going on in nanotechnology, what gets you most excited?
SMALLEY: I have to admit I'm just obsessed about carbon nanotubes. It's hard for me to go more than 10 minutes without talking about them. I think they are the coolest thing out there, and I think they'll have the greatest likely impact. But if I break myself away from that for a moment, I believe research at what I call the wet/dry interface is intellectually most intriguing to me. It may be that in 20 years from now that is where we'll look back and say we have made huge advances. What I call the wet side of nanotechnology is the machinery of cellular life. As we learn to interface this natural machinery with inorganic, electromechanical structures and systems engineered on the nanometer scale (the dry side of nanotechnology), vast new frontiers will be opened both in fundamental science and in practical technology.

Having said that, I can come back and say that nanotubes will be tremendously important to the wet/dry interface because they bring something new to the game. Organic molecules [carbon-containing molecules that are the basis of living things] are magnificently versatile, but there are some things they can't do well. In fact there are some things that biological systems have not yet been able to figure out, even after four-plus billion years. One thing is conducting electricity the way that metals do. Others are thermal conduction, and strength and toughness. Bones are very impressive, and so are teeth. But they aren't steel—let alone what nanotubes can do with strength and conductivity. So, being able to take a carbon nanotube and get it into the molecular biology realm—whether it's actually dissolved and is one of the players, or as a probe, or as part of an implant, as part of a new membrane—it's really bringing something brand new to the table in biology. Almost an alien thing.

TR: An alien thing because…
SMALLEY: Because it conducts electricity. It brings those properties you cannot get from other organic molecules. And it's still carbon, so it has organic chemistry. Here is an object that has, to a superlative degree, the aspects that we hold most central to the inorganic world: hardness, toughness, terrific strength, thermal and electrical conductivity. Things you just can't do with bone and wood. But it's made out of carbon. It's something that plays the game at the same level of perfection as molecules and life.

There is electricity in biological systems, but it's due to ions moving across membranes. Nerves work by electrical conduction; electric eels certainly have electricity. But that kind of electricity is different than the kind that runs in wires and houses, runs around computers, makes radios work. It's not the kind of electricity that has to do with electrons moving in coherent fashion over long distances with little loss. That's the property of metals, of inorganic compounds.



"I have to admit I'm just obsessed about carbon nanotubes. It's hard for me to go more than 10 minutes without talking about them. I think they are the coolest thing out there and I think they'll have the greatest likely impact."

TR: And now nanotubes could bring this kind of electricity to biological systems?
SMALLEY: Yes. They bring to molecular biology, to the things that go bump in the night inside a cell, a new toy to play with—something that conducts electricity.

TR: What will the new toys be?
SMALLEY: Stay tuned for the next millennium and we'll see. I could give some examples, but they'd seem rather pedestrian and ad hoc. Up until you add something like this to the mix, there is no way that the incredible machinery of living cells can construct something that can conduct electricity with the efficiency of metals. Here we have an [organic] molecule that can do that. I don't believe anyone is bright enough to predict the vast implications of that. But Lord knows how many years it will be before nanotubes are part of living cells. Before that, we can use nanotubes as probes into cells, as probes to detect the structure of molecules, to sequence DNA. These are wonderful new wires to do that.

TR: What projects are you and your group working on now?
SMALLEY: The single biggest focus is making nanotubes. That's what this company initially is about, turning on the spigot so that researchers around the world will have access to the most pristine-quality tubes that we can possibly make in large amounts at low cost. We want to make nanotubes available at small enough cost to let your imagination fly. These tubes come in three types: metals [excellent electrical conductors] and two types of semiconductors. I want to produce them with high enough efficiency that I can deliver a kilogram of a particular tube.

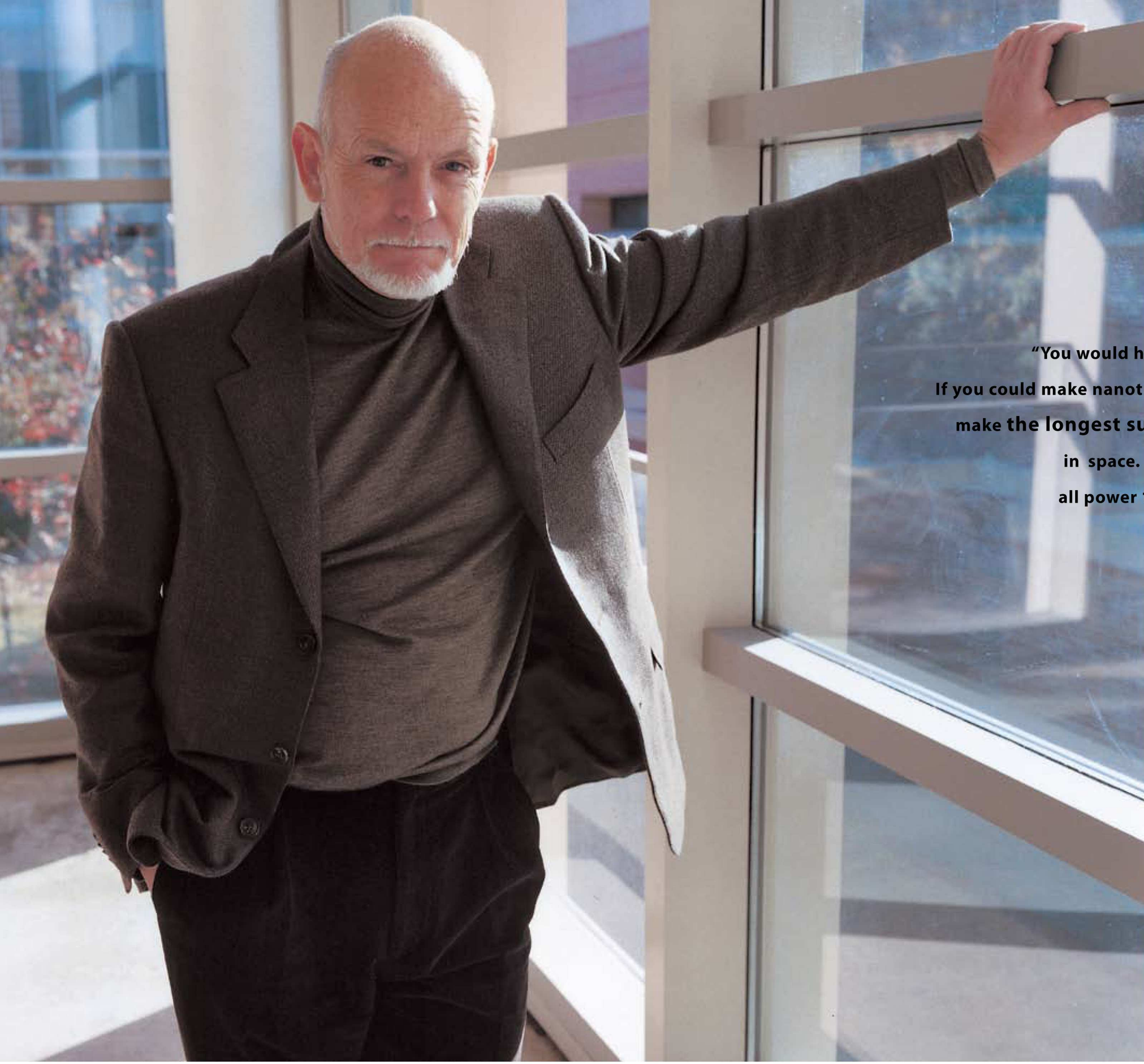
TR: So you're looking to make nanotubes more widely available. Other groups are looking at the nanotubes strictly from the point of view of applications. What are some of the interesting applications they're working on?
SMALLEY: In the nearest term, it looks like one application will be in [flat-panel] displays. A number of companies already have prototype displays using nanotubes. I won't be surprised if you see displays using nanotubes on the market within a few years.

Another area that will be quick is as additives in engineering plastics [used in structural or high-tech applications like computer housing]. You can give rise to antistatic behavior at even very, very low levels of nanotubes, and shielding for EMI [electromagnetic interference: such shielding is used to protect laptops and other portable electronics] at very moderate levels. Unlike anything else you add to polymers to make them antistatic or for EMI shielding, this will probably increase the engineering plastics' toughness and strength. Also, I expect within a few years that you'll find commercially available nanotube tips on atomic-force microscope probes. Use in nanotech gadgetry in general I expect will really flourish in the next five years or so.

What we would like to see is that the business develops so that there are economic incentives to build a large [manufacturing] process and get the price way down. At this moment, the cost of nanotubes is about $500 a gram. Calculate the numbers. That's nearly $230,000 a pound. In time this stuff will be made as a bulk commodity closer to $10 a pound or even below that. But you'll have to build a plant, and the market has to be out there. The rate at which the business develops is heavily dependent on these early markets.

TR: The hope is that as you get more and better materials out there, the applications will open up?
SMALLEY: That's right. And this next year will be a real watershed because our process will be putting out into the research community a minimum of 10 kilograms. The total production of single-wall nanotubes of any quality up to this time has probably been less than one kilogram.

TR: Of course, none of those shorter-term applications really fulfill the huge promise of nanotubes, do they? Such as acting as an electrical conductor in a biological environment?
SMALLEY: And what I was talking about before was only on the wet/dry interface. Then you get back to the dry side. There is a "lunatic fringe" of the nanotube world that we haven't talked about yet. Over the next year there will be in my lab, and I suspect in many around the world, a big



"You would have the strongest damn thing ever made in the universe. If you could make nanotube fibers cheaply and in a continuous length, you could make the longest suspension bridge you ever heard about, elevators in space. But 'buckycables' would also be terrific conductors of electricity for all power transmission cables in the world."

push to develop means of spinning continuous fibers—macroscopic fibers—of nanotubes with a high degree of orientation [the nanotubes would be aligned like uncooked spaghetti in a box]. I think that's going to be successful, and it will be something special.

In one direction nanotubes are the strongest damn thing you'll ever make in the universe and are excellent electrical conductors; in the other [perpendicular] direction, they're floppy, and the electrical conductivity is quite poor. So, in materials where you want electrical conduction, you care about how well the nanotubes are aligned. I believe it is going to be possible to make continuous fibers of nanotubes in an efficient spinning process that will have the tubes all aligned. I wouldn't call that the lunatic fringe; I think it's going to happen. But now let's talk about the really lunatic extreme. What if these spun fibers were, instead of a micrometer long, a kilometer long?

TR: In theory you could make nanotube fibers a kilometer long?

SMALLEY: In theory you can make them to Alpha Centauri. What would be the strength of a long fiber? You would have the strongest damn thing ever made in the universe. Can we ever make that? And what good would it be? If you could make it cheaply and a continuous length, you could make the longest suspension bridge you ever heard about, elevators in space. But "buckycables" would also be terrific conductors of electricity. It is the logical replacement for all power transmission cables in the world. That's at the lunatic fringe, but I can say that because I'm an advocate of it.

TR: As you know, there has been a growing effort to use organic molecules as tiny switches in nanoelectronic devices *(see "Molecular Computing,"* TR *May/June 2000)*. What role do you expect that nanotubes will play in molecular electronics?

SMALLEY: In the long term, it seems they must figure in—because they're nano and they conduct electricity. Whether or not they'll figure into nanoelectronic gadgetry in the next decade, I don't think anyone is smart enough to know. In fact, no one is smart enough to know if there will be any nanoelectronic gadgetry in the next decade. But most people agree that if you had to pick the electrical conductor in nanoelectronics it will eventually be a nanotube. We'll just have to stay tuned to see how quickly that happens.

TR: For now, even something as simple as putting a nanotube where you want it is still a challenge, isn't it?

SMALLEY: We are really children, not even children, babies, in understanding how nanotubes work.

TR: Still, I was thinking how quickly the field of nanotech has moved. When I interviewed you a few years ago, we talked a lot about the hype surrounding nanotechnology *("The Hope & The Hype,"* TR *March/April 1999)*. Now, with more and more serious scientists getting involved, it seems to have moved beyond that.

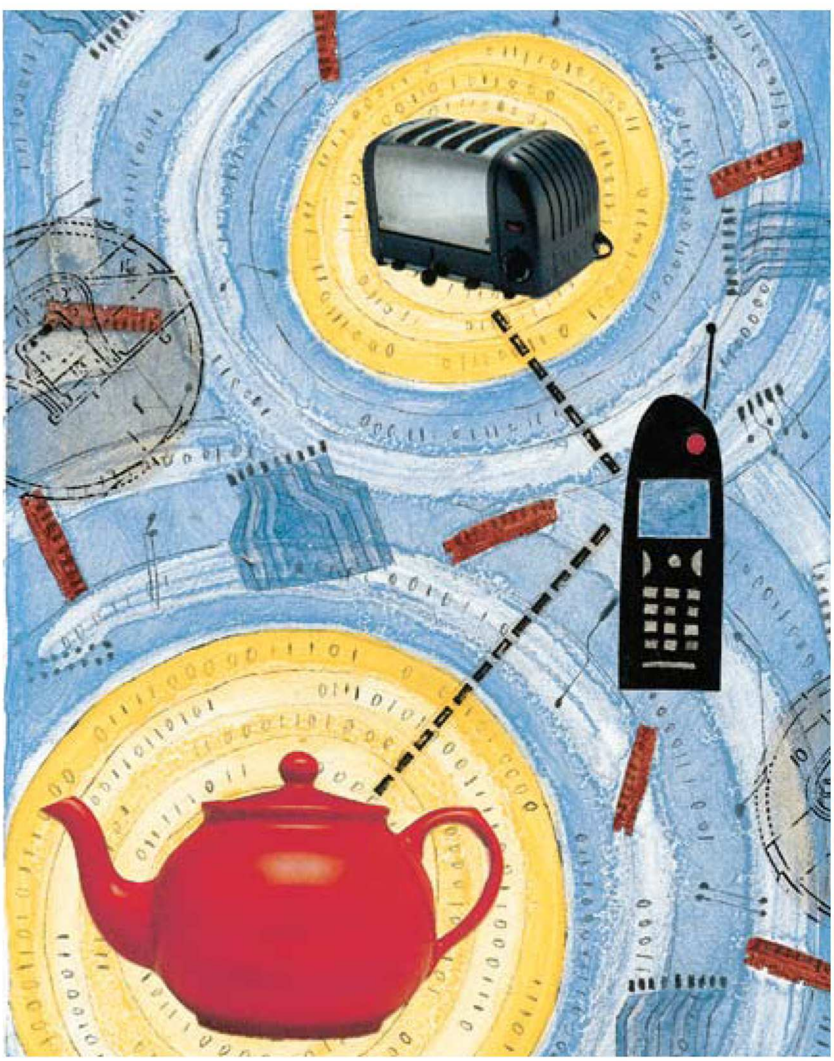
SMALLEY: That was the key factor, serious scientists getting involved that are far removed from "nanobots" [nanoscale robots figure in many speculative visions of nanotech]. We haven't quite completed the task of "de-nanobotting" the field. But the main point is that nanotechnology is so important that we don't want it to be associated with just nanobots. Whether or not they can ever happen is another issue, but there's a so much broader reality to nanotechnology—and in ways a much more interesting one. ◊

Internet on a Chip

TEN YEARS AGO, ONE OF THE biggest hits at a major trade show on new network technology was the Internet Toaster. By typing a command on a networked computer anywhere in the world, you could turn the modified Sunbeam Deluxe on and off, or have the toast pop up.

The Internet was still small back then, with a mere 300,000 computers online. But it was growing like a weed. And one of the big jokes was that we would soon be putting our toasters, microwave ovens, and refrigerators on the Net. The joke was all the funnier because nobody could quite figure out why this kind of connectivity for household appliances would be desirable: we just knew that networked appliances would be part of our collective future.

Connecting a toaster to the Internet was not easy. For starters, the toaster needed a computer powerful enough to "speak" the so-called Internet Protocol—the digital standard that allows computers on the Net to communicate with one another. The contraption's creators—Internet pioneers John Romkey and Simon Hackett—linked their toaster to a power switch that was in turn hooked to the printer port of a Net-connected laptop computer. Romkey and Hackett tinkered for a year to get it to work.



YUMI HEO

Fast-forward a decade. More than 300 million computers are connected to the Internet—but there aren't many more household appliances than there were back when the Internet Toaster debuted. The inexpensive microcontrollers that are typically found in microwave ovens and fancy toasters lack the power to implement the Internet Protocol and therefore cannot practically go online.

That barrier is starting to crumble, thanks largely to a bit of technical wizardry by Santa Clara, CA, startup iReady. This company has reduced the Internet Protocol circuitry onto a silicon chip. The device, dubbed the Internet Tuner, lets companies connect dumb machines to the Internet without using expensive microprocessors. This technology could be the engine behind home networks of the next decade—but the developments made so far already have me worried about the potential for abuse.

I still can't figure out why you would want to put a toaster on the Net. But early this year, Japanese housewares manufacturer Zojirushi plans to begin marketing an Internet-enabled hot pot that can send short messages to cellular telephones using a built-in wireless modem. Zojirushi will pitch the hot pot to the adult children of aging parents. Whenever the pot is used, explains iReady president Ryo Koyama, it automatically transmits a message letting the child know that the parents are okay and enjoying a cup of fresh tea.

iReady doesn't market chips. Instead, it sells intellectual property—specifically, the wiring diagram for the tens of thousands of transistors and resistors that constitute the Internet Tuner. Companies such as Zojirushi can then use this information to build Internet functionality into the silicon chips that they are already putting into their products—an incremental cost of virtually zero. Essentially, the iReady

Distilling the essence of Internet communications into silicon makes it practical to wire dumb appliances to the Net. But will merry pranksters wreak havoc with your coffeepot?

technology makes it possible to add Internet access to a device for little more than the cost of the patent license.

Other applications are more commercial and less social. A soda vending machine equipped with the Internet Tuner, for instance, could report its status via the Internet to a regional distributor. There's nothing revolutionary about soda machines reporting their inventory over dial-up networks; what's new is the idea of using the Internet as a unified network for collecting and distributing this and other kinds of data. Consider Zojirushi's hot pot. It never would have been cost-effective for the company to build its own wireless data network. What can make a lot of economic sense, though, is renting time on a network that already exists—particularly if the typical hot pot is sending less than 500 bytes of data each day. The Internet is ideal for this purpose. Thus the ability to implement the Internet's basic communications protocols in silicon will dramatically lower the cost of building online access into relatively dumb devices, which in turn should cause the number of Net-connected devices to skyrocket.

In the United States, companies such as EarthLink and America Online have built huge Internet dial-up systems. Serving mostly residential customers, these networks are nowhere near capacity during business hours or late at night. Combine iReady's Internet dialing technology with a cheap modem and you have a recipe for wiring the world.

Take this idea from YSI, a maker of environmental measuring instruments based in Yellow Springs, OH. YSI recently partnered with Aquadyne Computer of San Diego to create a system for monitoring the quality of water used in aquaculture. Sensors make a variety of water quality readings, then dump the data onto the Internet. The system can also monitor parameters like dissolved oxygen and automatically send e-mail messages when it detects a problem. "In a typical project like this you would need to embed a 16- or 32-bit processor and 100 or so kilobytes of memory," says Aquadyne president Dean McDaniel. By adopting iReady's technology, YSI cut the component cost of Internet access in its hardware from $79 to $9.

If iReady's technology becomes widespread, Koyama says, it could change the way that Internet service providers collect revenue. Today these companies mostly sell "all-you-can-eat" service for about $20 per month. Companies that build the Internet Tuner into their products are likely to want a different kind of pricing. The idea is that a million devices might each dial into the Net once or twice a day and stay online for less than a minute. In all likelihood, manufacturers will purchase Internet bandwidth in bulk and then fold the cost of the service into the price of the appliances—an approach that would take less accounting than managing a couple million individual accounts or implementing some sort of global micropayment system. To kick-start the new pricing model, iReady is forming DeviceNet—a consortium of Internet service providers dedicated to providing online access to devices other than PCs.

While companies have developed the technology that such a system requires, they don't necessarily possess the wisdom that such capabilities demand. Pervasive telemetry will create unprecedented opportunities to collect personal information. An engineer at Zojirushi, for example, proudly showed iReady's Koyama a cell phone, displaying a message indicating that the engineer's grandmother had used her wireless hot pot that very morning.

"What does she think of this?" Koyama asked the engineer.

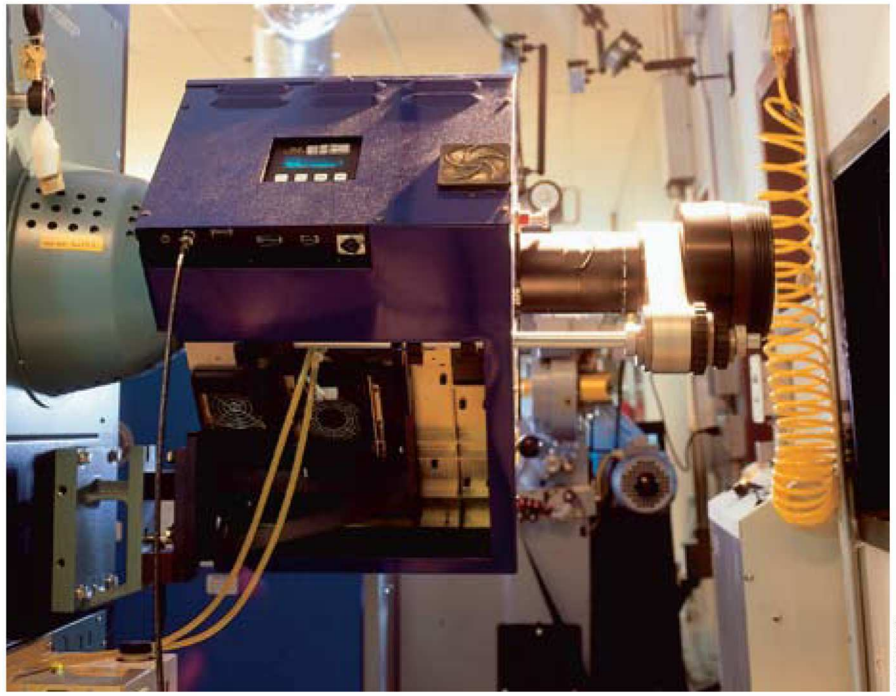
"Well, she doesn't know!" answered the engineer—who then said that if his grandmother were aware that her hot pot was monitoring her actions, she almost certainly would object. "There is this whole Little Brother aspect" to the project that is a little unsettling, Koyama concedes.

Security presents another tricky issue. iReady's second component set is designed for wired networks, rather than dial-up services. Called the Internet Tuner Ethernet, the technology is designed to be bundled into all sorts of equipment that could be wired around an office or building—including thermostats, valves, lights and even cash registers. But iReady's Ethernet logic makes no provision for security—no usernames, no passwords and no encryption. If you can reach the Ethernet Tuner over the Internet, it will tell you its secrets.

Koyama says he's not concerned with this issue, explaining that Ethernet Tuner is designed to be used behind a company's firewall. But given all the security lapses that have been publicized in recent years, that's hardly reassuring. Many Ethernet Tuners will undoubtedly end up on the open Net—and even many of those that stay behind firewalls will lack proper protection. Experience has shown that when security protections are not built in from the beginning, many users will neglect to add them later. I can imagine Internet pranksters searching for Ethernet Tuner-enabled light switches and then making the lights flash on and off until the company disconnects from the Net. And no doubt the pranksters can come up with something far worse.

iReady is sure to respond if there are any high-profile incidents. But its patent creates a unique opportunity. If iReady builds in technologies that protect privacy while enhancing security, such protections will become standard on billions of devices over the next few years. Let's hope that the company rises to the occasion. ◊

VISUALIZE



WEBB CHAPPELL

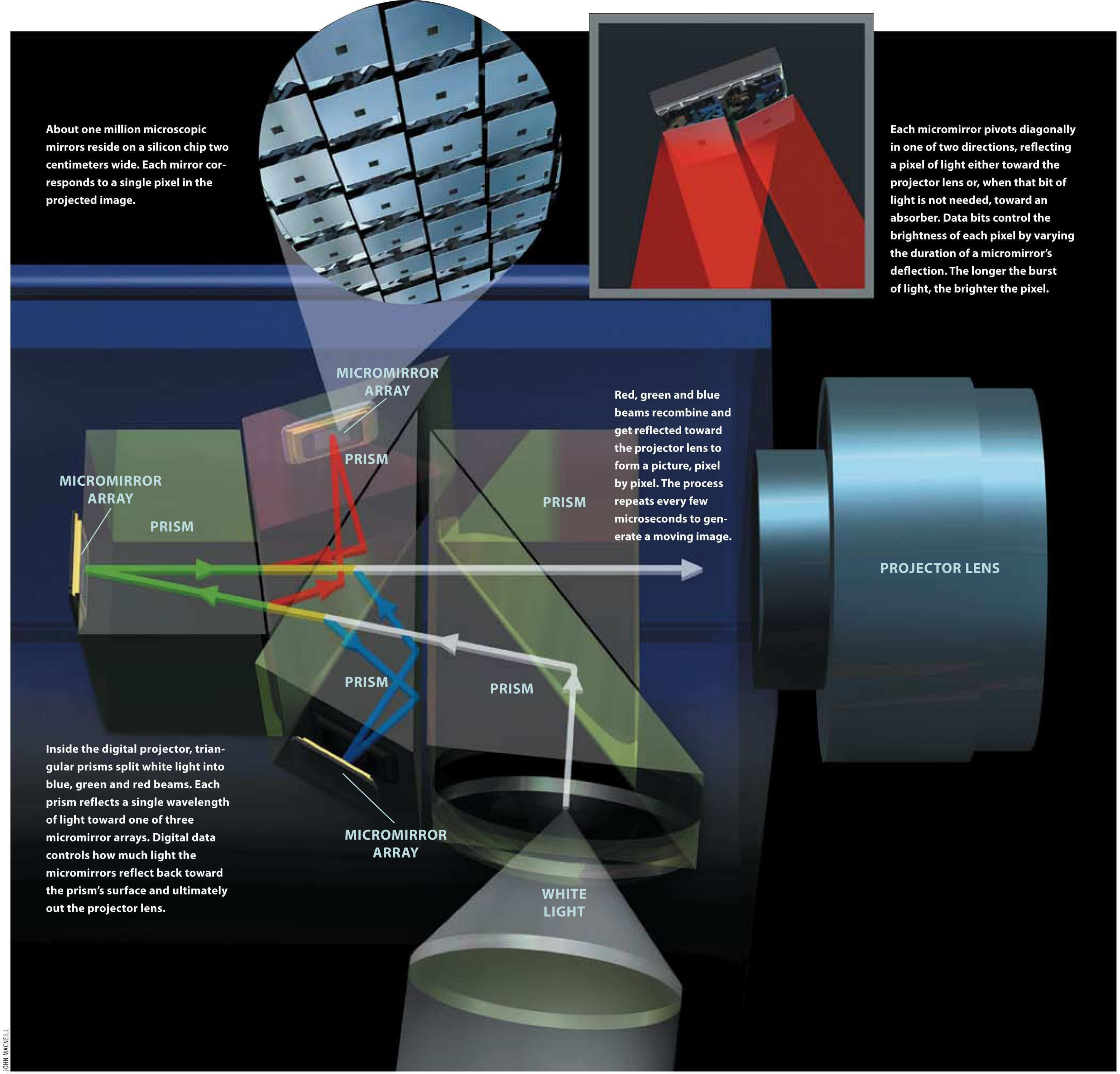
Digital Movie Projection

Film goes the way of vinyl as cinema is transformed into a stream of flowing digital data.

Digital action, sound and computer-animated graphics have become as much a cinema staple as the dancing soft drink and fries. Yet although motion-picture production is turning digital, in most theaters, projection is still a distinctly old-fashioned analog affair. Recently, Texas Instruments developed technology to keep the movie digital all the way to the screen. In 1996, it unveiled a projector that assembles the moving image not from film but from a stream of bits. The bit stream controls an array of micromirrors inside the device that manipulate beams of colored light and turn them into moving pictures.

The heart of the system is a network of over one million moveable mirrors on a silicon chip two centimeters wide. Each mirror measures a scant 16 micrometers square and teeters diagonally on a pivot to reflect light in one of two directions. Digital data controls where and how fast a pulse of light is reflected. The mirrors are nimble enough to handle a new light pulse every five to 10 microseconds. With this rapid switching rate, and a gap of only one micrometer between mirrors, a seamless image is produced that lacks the pixel effects marring some computer graphics or the familiar flicker of film. Like CDs, so-called digital light processing also avoids the wear and tear that causes analog information to deteriorate over time.

Digital projection debuted in 1999, when Texas Instruments teamed with Lucasfilm to present *Star Wars: Episode I—The Phantom Menace*. Since then, more than 30 cinemas worldwide have used the technology to present *Toy Story 2*, *Bicentennial Man*, *Dinosaur*, *Tarzan*, *Mission to Mars*, *Fantasia 2000* and *The Emperor's New Groove*. While these computer-generated movies are well suited for digital projection, the technology is not restricted to them. Conventional film can be converted to data and then displayed with a digital light processor. For this technology to really come into its own, however, moving pictures must be produced digitally from start to finish—an industrywide change still in its infancy. ◊



JOHN MACNEILL

The Director Next Door

A FEW MONTHS AGO, I STUMBLED onto a childhood artifact. When I was 10 or 11, I had drafted a contract with the kid across the street forming a motion picture production company. Signing our names in crayon on cardboard, we vowed to save our allowances to buy a Super 8 camera and then start making monster movies. I remember devising scripts and perfecting my vampire makeup, while the kid next door practiced his wolf-man shuffle. For the life of me, however, I can't recall what we were planning to do with these films once we made them.

Amateur films have always been home movies. We make them in our houses, we make them in our neighborhoods, and we show them in our living rooms. Digital cinema may change all of this, at last providing a means of distribution and exhibition so that home movies can become public movies. Today, kids and adults are making their own *Star Wars* films, using desktop computers to create special effects that would have cost Industrial Light & Magic a fortune just a decade ago. And even more remarkably, we can all watch them on the Web.

Digital cinema could do for movies what the photocopier did for print culture. In the 1970s and '80s, we saw the explosion of newsletters and 'zines, documenting the experiences of folks living in retirement homes, working in minimum-wage jobs or slam dancing in mosh pits. Now, the introduction of cheap and lightweight digital video cameras, PC-based digital editing software, and streaming-video distribution on the Web puts the resources of filmmaking in the hands of an equally broad range of citizens and thus expands the potential for grassroots creativity.

Some skeptics may grumble that they have heard this all before: a succession of previous technologies promised more democratic access to the means of media production, only to remain on the margins. Yet this misreads the nature of the current revolution. Digital cinema may describe a range of technological changes, particularly in cameras and editing suites, but what's really different this time is the advent of Web-based film distribution. That's what turns digital, or even conventional, filmmaking into digital cinema. In the past, amateur films never made it into the multiplexes. Local activists had to struggle ceaselessly with city councils to protect public-access cable, one of the few venues for such films. But digital cinema is meeting the challenge of distribution at several levels—at the commercial portals, hungry for product, that have put hundreds of films on their sites; on various more specialized fan or subcultural networks; on sites built by filmmakers to showcase their work.

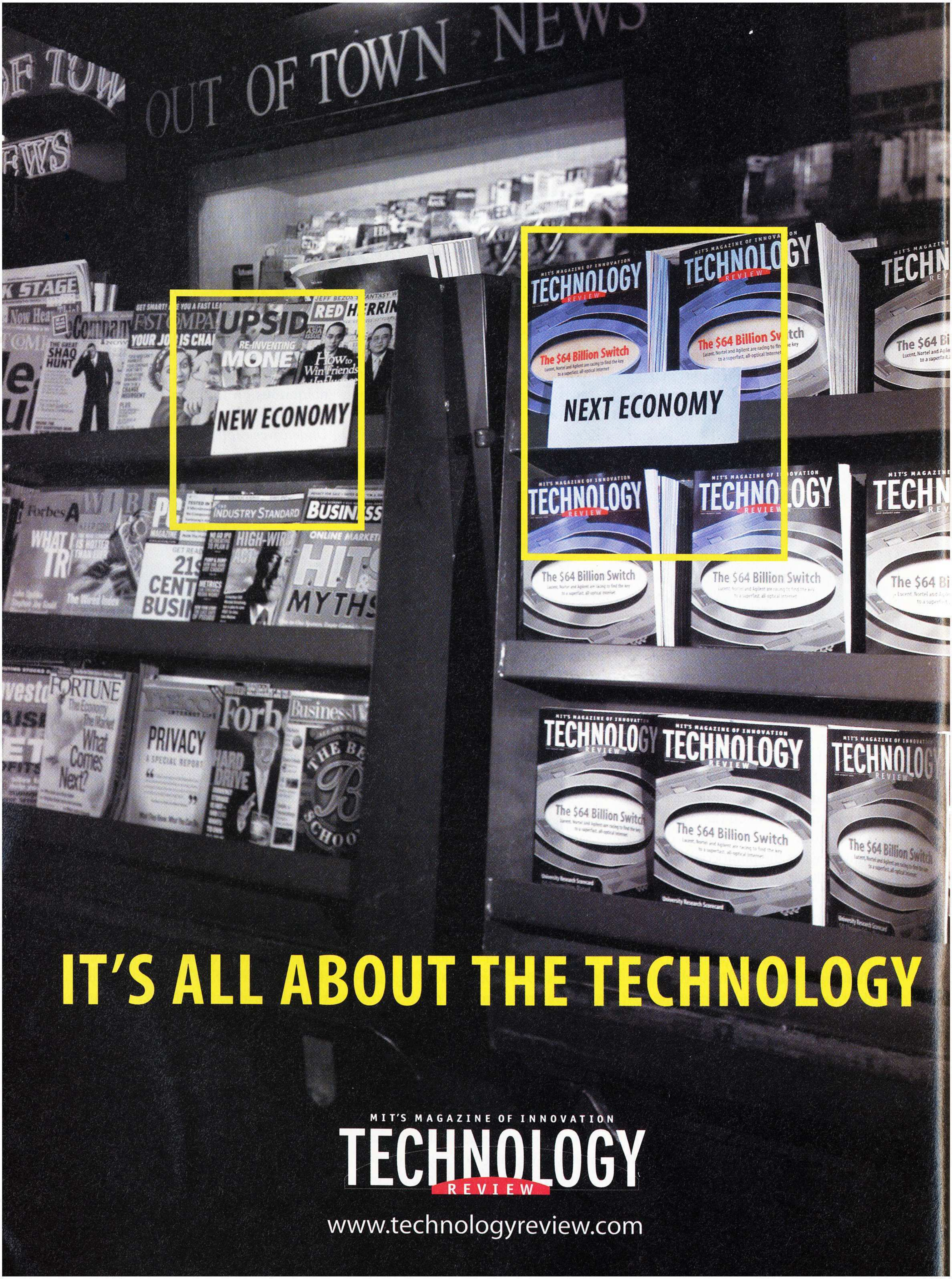
Digital cinema puts the resources of filmmaking into the hands of a broad range of citizens and expands the potential for grassroots creativity.

Today, if you know where to look on the Web, you can find fascinating examples of this new garage cinema—from animated shorts to poignant documentaries. Cambridge, MA-based media collective Big Noise and Seattle's Independent Media Center, for example, distributed camcorders to over 100 media activists in Seattle for the contentious 1999 World Trade Organization conference, and the result was the powerful *This is What Democracy Looks Like*, which you can order at www.thisisdemocracy.org. Digital films may be as profound as the Rodney King tape or as superficial as *America's Funniest Home Videos*. But every art form needs room for people to take risks and make mistakes. We can't have great cinema if there isn't someplace where beginners can make damn awful cinema; meanwhile, some digital movies are more bold and original than anything to hit the big screen in ages.

We can already see evidence that the public (and the mainstream industry) has embraced this new style of grassroots filmmaking. *South Park*, one of the biggest commercial successes of the late 1990s, emerged from a video "Christmas card" that became ubiquitous on the Web. Several animated series from the Web, including *Undercover Brother* and *Starship Regulars*, have been contracted for feature-film or commercial-television production. Perhaps most surprisingly, when Amazon.com offered video copies of *George Lucas in Love*, an early digital film success, it outsold *The Phantom Menace* in its opening week.

And beyond the commercial potential lies this tantalizing possibility: cinema may become, like poetry, an intimate and spontaneous mode of personal expression. As Francis Ford Coppola explained in the documentary *Hearts of Darkness*, "For me the great hope is now that 8-millimeter video recorders are coming out, people who normally wouldn't make movies are going to be making them. And that one day a little fat girl in Ohio is going to be the new Mozart and make a beautiful film with her father's camcorder. For once the so-called professionalism about movies will be destroyed and it will really become an art form."

None of my friends became a new Mozart. We never really got around to making those monster movies. But maybe Coppola is right, and somewhere in Ohio the creation of a masterpiece is already underway. Maybe, even, it's happening in your own rec room. ◊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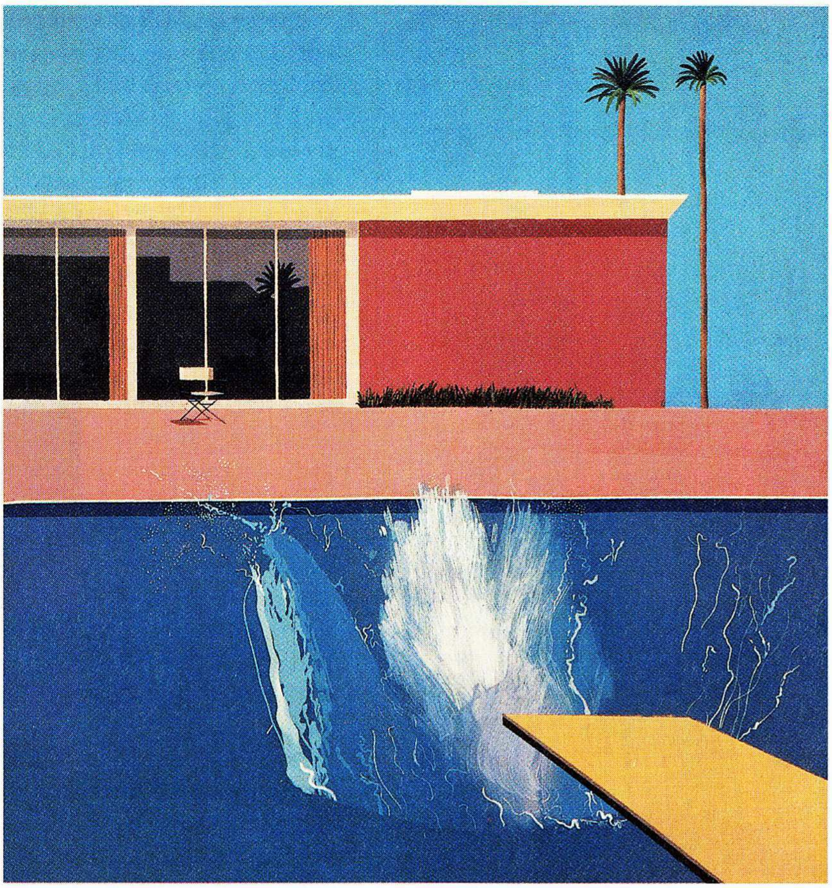

David Hockney
A Bigger Splash, 1967
Acrylic on canvas
96" x 96"
© David Hockney

ESSAY | MICHAEL MORITZ

A Bigger Splash

As high-flying dot coms tumble back to earth, a leading venture capitalist reflects on the nature of Silicon Valley.

ONE OF MY FAVORITE PAINTINGS is an early work by the British artist David Hockney. The picture has become an icon of California. It depicts a home in Los Angeles, but it could easily pass for a scene from one of the grander suburbs of Silicon Valley. It shows an endless blue sky, an angular house clad in glass, a pair of palm trees, a diving board and ripples of white paint emerging from an iridescent swimming pool. The painting's title is *A Bigger Splash.*

I've occasionally thought about this painting and its title during the course of the last couple of years. It sometimes seems like a parody of Silicon Valley: the beckoning promise and expanse of the flat pool, the explosive squiggles of paint that threaten to splatter the sky, the invisible nature of the creature that caused the perturbation, and the sheer, high-spirited boastfulness of the title.

You would be hard pressed to think of a series of bigger splashes or more optimistic statements than those contained in the press releases issued by so many startups just one year ago. Think of those eagerly greeted birth announcements that have since turned into obituary notices (or pending obituary notices): Kibu, Boo, Eve, drkoop, Chipshot, living, Miadora, Mercata, Garden, MVP, Bigwords, Mondera, Pets, HomeWarehouse, MotherNature and TheStreet (all of which have ".com" in their official names), Della & James, iVillage, Bravo, Internet Capital Group, idealab!, Fogdog Sports and, of course, that wonderful epitome of understatement, divine interVentures. It was a period when the only motto that seemed to matter was "Time to Empire," and when entrepreneurs and venture capitalists had been portrayed as salvation from all the world's woes.

But this new generation of Emperors and Empresses was as woefully ignorant of the fate of its predecessors as all willful optimists. Think back to a prior generation and the spring of 1985, when the future was all about personal computing hardware and software. Then the equivalent roster contained names such as Gavilan Computer, Osborne Computer, Kaypro, NorthStar, VectorGraphic, Imagic, Fortune Systems, VisiCorp, Borland, Activision, Software Publishing, Forefront, Victor Technologies, WordStar International, Priam and Dysan. Back then, newspapers and magazines panted just as hard as they turned Silicon Valley mortals into icons.

If you survey all these former highfliers and ponder the causes of their demise, you might conclude that beyond the names and industry segments nothing much has changed about Silicon Valley. On the whole, you would be right. Yes, the traffic has become heavier, salaries have risen, rents have escalated and today's company founders no longer recognize former heavyweights such as Rod Canion or John Sculley. But whether it is the spring of 1985, or the spring of 2000 or, I daresay, the spring of 2005, there are many things that are eternal about Silicon Valley.

There were, of course, some differences in the latest series of Silicon Valley splashes. In retrospect, it seems that the dawn of the consumer's Internet was the emancipating call for anyone who had ever harbored the slight-

est aspiration to be an entrepreneur. For the first time the majority of companies were started by people with liberal arts backgrounds rather than degrees in computer science or electrical engineering. Suddenly, everyone could register a domain and cobble together a Web site. In the pandemonium that followed, it was easier to form a company than to open a corner store, publish a newsletter or start an auto-repair shop. Also, for the first time, the flow of information about a new enterprise became close to perfect: an Internet company started in Santa Clara County would almost always be cloned a few weeks later in Shanghai, Stuttgart or Stockholm.

The only difference between this latest burst of euphoria and other eras of excess (and success) in Silicon Valley was one of degree. Every promising new market segment—especially where there is a visible example of early success—has always been guaranteed to attract a lot of interest. The list of previous causes of enthusiasm is almost endless. Here are a few examples: flash memories, programmable logic devices, workstations, T1 multiplexers, storage mechanisms (magnetic, tape or solid-state), personal computers, personal computer software, mini-supercomputers, relational databases, object-oriented databases, artificial intelligence, video games, local area networks, information technology service companies, and wide area networks. It does not take much notoriety to transform one example of success into a fad. It also takes only one poorly managed company intent on buying market share at any cost to create a bloodbath in any category.

It doesn't matter whether it is the spring of 1971, 1981, 1991 or 2001: there are a few things that, I suspect, will always be true about Silicon Valley. Every new decade will only spawn a handful of companies that deserve to become enduring members of the Nasdaq Stock Market. Most of the companies orga-

nized in the valley will become product lines of larger companies, features of product lines of larger companies or they will fail.

But if that seems too bleak or cold an assessment, it is hard to conceive of a place where the rules of real success are better understood than Silicon Valley. There will always be massive opportunities for any companies that solve a real need for lots of customers. The most acute of

A FEW THINGS WILL ALWAYS BE TRUE ABOUT SILICON VALLEY. EVERY NEW DECADE WILL ONLY SPAWN A HANDFUL OF COMPANIES THAT DESERVE TO BECOME ENDURING MEMBERS OF NASDAQ.

these needs usually will only be solved by the commercialization of some new technological development. On the whole, companies that answer burning problems will quickly come to operate with high margins and start to generate cash—the mother's milk of all prosperity and the lubricant of growth.

It is a pretty simple formula. Every time we tinker with the equation or delude ourselves into believing that tomorrow will be different, we will get into trouble. Conversely, every time we stay true to what has worked and help to form and organize companies run by people with a real passion for their business, sympathy for their customers and desire to make money, we will be participants in something that really does deserve the label "a bigger splash." TR

Michael Moritz is a partner at Sequoia Capital in Menlo Park, CA, the venture capital firm that has helped start and organize Cisco Systems, Yahoo!, Vitesse Semiconductor, Apple Computer, RedBack Networks and many other high-technology companies.

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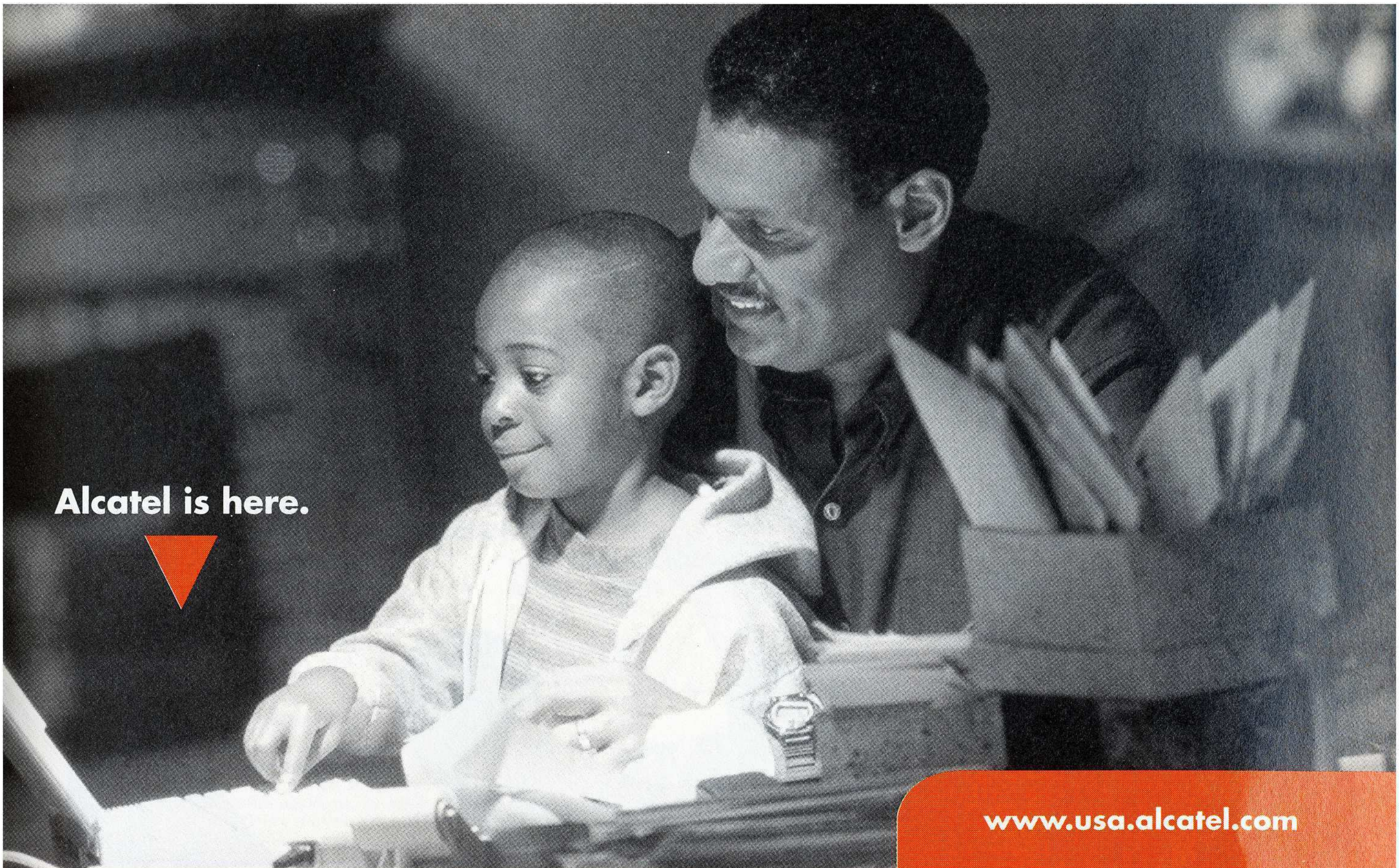

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REPRODUCED FROM RADIO ELECTRONICS, OCTOBER 1950, BY PERMISSION OF GERNSBACK PUBLICATIONS.

Simple Simon

Personal computers have been around longer than you think

QUICK—NAME THE FIRST personal computer. No, it wasn't the 1981 IBM PC, which introduced "PC" to the vernacular. Nor was it the 1977 Apple II. Not even the 1975 Altair—the first machine to run Microsoft software—represents the true origin of this species.

The first digital PC showed up in 1950, the creation of early computer entrepreneur Edmund C. Berkeley. Berkeley caught computer fever while working as an analyst at Prudential. He pushed for Prudential's involvement in the development and use of UNIVAC, the first general-purpose commercial computing machine. In 1948, Berkeley founded his own computer company, Berkeley Associates, in Newton, MA. There he conceived of Simon, which he first described in his 1949 book *Giant Brains, or Machines That Think*.

Like present-day PCs, Simon was programmable, affordable to an average professional and could be operated with the aid of only a simple training manual. Shown above with Berkeley, Simon consisted of 129 electromechanical relays, a stepping switch and a paper-tape feed for inputting data. It performed simple arithmetic and logic operations, displaying the results with an array of five lights. Twenty-five years later, the Altair didn't do much more.

Berkeley built the first Simon with a team of Columbia University students in 1950. Simon's purpose was to demonstrate the accessibility and utility of electronic computers by giving people hands-on experience. He marketed plans for Simon rather than assembled systems; more than 500 copies of the plan were eventually sold. The machine, which cost $300 to $600 to build (equivalent to about $2000 to $4000 today), helped illustrate basic computing concepts without huge machines that only a few elite institutions could afford.

Although Simon's relay technology was a dead end, the machine and its inventor influenced popular acceptance of an embryonic technology and also inspired other early computing innovators. In fact, computer graphics pioneer Ivan Sutherland wrote his first programs on a Simon. Berkeley continued to innovate, building computers and early programmable robots, as well as the foundation for publications like *TR*: he started the first computer magazine, *Computers and Automation*. ◊

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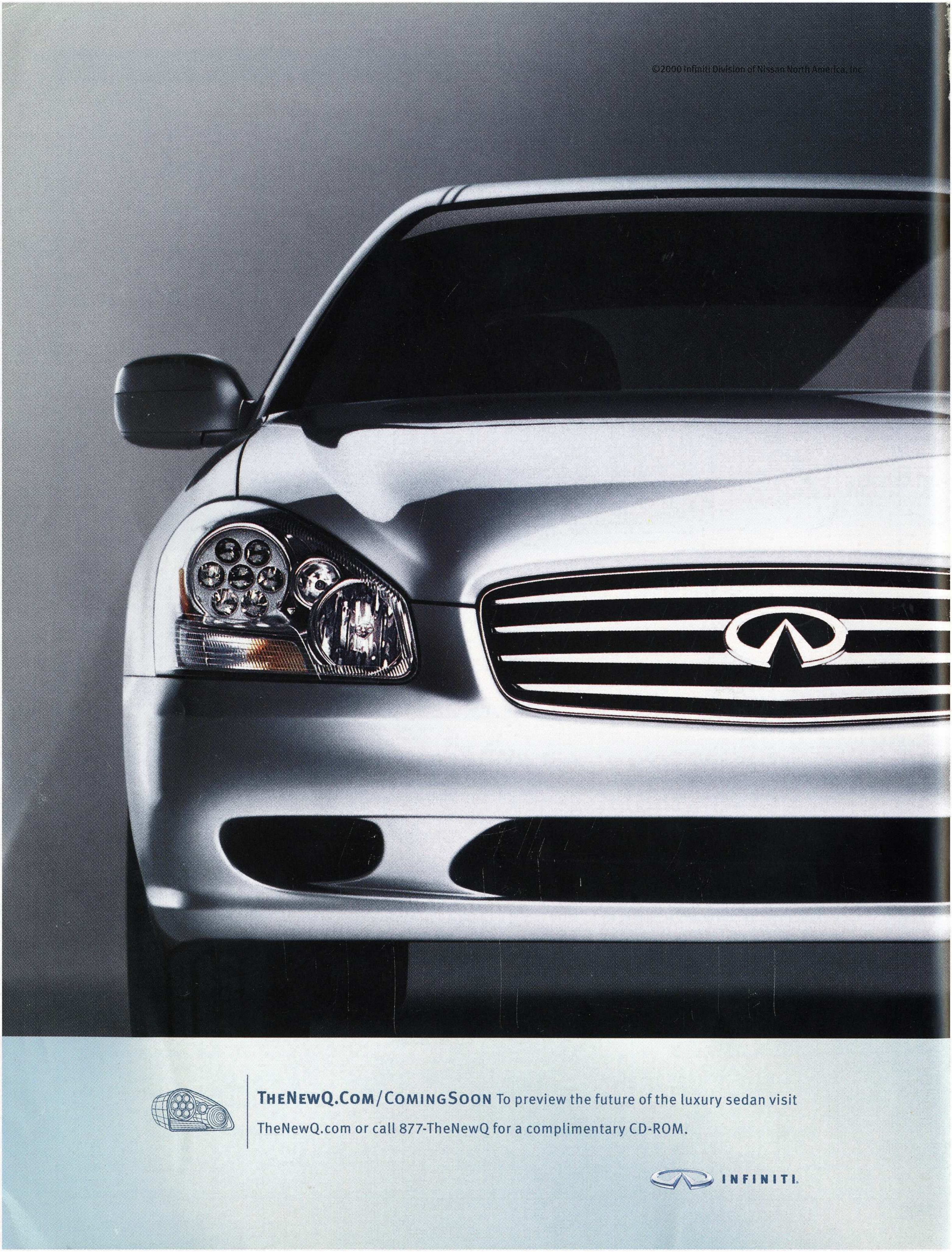

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